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vol. 1

STATE OF CALIFORNIA  
GOODWIN J. KNIGHT  
GOVERNOR

PUBLICATION OF  
STATE WATER RESOURCES BOARD

Bulletin No. 12

VENTURA COUNTY  
INVESTIGATION

Volume I  
TEXT



October, 1953  
Revised April, 1956

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SECRETARY

October 1, 1953

ADDRESS ALL COMMUNICATIONS TO THE SECRETARY

Honorable Earl Warren, Governor, and  
Members of the Legislature of the  
State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 12 of the State Water Resources Board, entitled "Ventura County Investigation", as authorized by Chapter 1514, Statutes of 1945, as amended.

The Ventura County Investigation was conducted and Bulletin No. 12 was prepared by the Division of Water Resources of the Department of Public Works, under the direction of the State Water Resources Board. Funds to meet the cost of the investigation and report were provided as follows: State of California (State Water Resources Board), \$30,000; County of Ventura, \$30,000. Information and data developed in the current state-wide investigation with state funds were used in connection with this investigation.

Bulletin No. 12 contains an inventory of the underground and surface water resources of Ventura County, estimates of present and probable ultimate water utilization, estimates of present and probable ultimate supplemental water requirements, preliminary plans and cost estimates for local water development works, and for works for importing water from sources outside the County.

Very truly yours,

A handwritten signature in cursive script, appearing to read "C. A. Griffith".

---

C. A. Griffith  
Chairman



## ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government, cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

Board of Supervisors, County of Ventura  
Ventura County Flood Control District  
Ventura County Water Survey  
Los Angeles County Flood Control District  
United Water Conservation District  
Santa Clara Water Conservation District  
Metropolitan Water District of Southern California  
California State Division of Highways  
California State Department of Fish and Game  
United States Geological Survey  
United States Soil Conservation Service  
United States Navy Department  
Harold Conkling, Consulting Engineer  
John Mann, Consulting Geologist  
Southern California Edison Company  
American Pipe and Construction Company  
Fruit Growers Laboratory, Inc.

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## CHAPTER I. INTRODUCTION

In common with many other portions of southern California, Ventura County has recently experienced an increase in water utilization during a period of severe drought, and as a result is confronted with the necessity of developing additional water supplies to meet its expanding needs. Water resources problems of Ventura County are manifested in perennial lowering of ground water levels, sea-water intrusion to pumped aquifers, degradation of ground water quality, and general diminution of surface and ground water supplies during periods of drought to quantities inadequate to satisfy requirements. The initial alleviation of these problems will involve further regulation of the erratic local water supply, so that waste conserved during wet periods can be made available for beneficial use during periods of drought. Final solution of water problems of Ventura County will lie in importation of water supplies from outside sources.

### Authorization for Investigation

In consideration of the critical water supply situation in Ventura County, the Board of Supervisors of the Ventura County Flood Control District presented a resolution to the State Water Resources Board, dated October 24, 1950, requesting a comprehensive investigation of the water resources of the County. The State Water Resources Board referred the request to the State Engineer for preliminary examination and report on the need for such an investigation and an estimate of its scope, duration, and cost.

The State Water Resources Board on April 6, 1951, approved a recommendation by the State Engineer, based on findings of the preliminary examination, for a two-year cooperative investigation, and authorized negotiation of an agreement with the Ventura County Flood Control District. The agreement, between the State Water Resources Board, the County of Ventura, and the State Department of Public Works acting through the agency of the State Engineer, was executed on April 15, 1951. It provided that the work

"shall consist of (1) a complete review of reports of prior investigations concerning the water resources of Ventura County; (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service agencies, (c) ultimate water requirements, (d) preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent, (e) required supplemental water supply from outside sources, (f) possible outside sources for required supplemental supply, including preliminary plans for importation and estimates of costs; and (3) the formulation of a report thereon."

This agreement authorized provision of funds to defray costs of the investigation for one year. A supplemental agreement executed by the same parties on May 1, 1952, authorized funds to complete the investigation and report.

Funds to meet the costs of the investigation and report to the extent of \$60,000 were provided on a matching basis, \$30,000 from the County of Ventura and \$30,000 from the State Water Resources Board. Of the funds made available under the agreement, not more than \$10,000 were to be expended on exploration work and surveys at dam and reservoir sites. Additional funds have been expended in investigation of Ventura County by the State Water Resources Board in connection with the current State-Wide Water Resources Investigation, and by the State Division of Water Resources for studies of quality of water pursuant to sections 229 and 230, Division 1 of the California Water Code, certain results of which have been used in connection with the Ventura County Investigation.

Copies of the two agreements between the State Water Resources Board, the County of Ventura, and the Department of Public Works are included in Appendix A.

#### Related Investigations and Reports

Review was made of reports of prior investigations dealing with various phases of water resources problems of Ventura County, extending back to and including Division of Water Resources Bulletin No. 46, "Ventura County Investigation, 1933". Investigational reports prior to 1933 were not reviewed, as any pertinent data contained therein were evaluated and utilized in the preparation of Bulletin No. 46.



Pursuant to a request by the Board of Supervisors of the Ventura County Flood Control District on July 27, 1951, there was submitted to that Board in November, 1951, a report entitled "Review of 'Report on Casitas Dam and Reservoir' by Board of Consultants, May 1, 1951".

On November 28, 1951, the Board of Supervisors of the Ventura County Flood Control District requested a review of a report, prepared by the staff of the District, on a plan of distributing water from the proposed Casitas Reservoir. In accordance with this request, a report entitled "Review of 'Memorandum on Distribution of Water Stored in Casitas Reservoir and Matilija Reservoir to Lands and Users in the Year 1975, November 1951'" was prepared and submitted to the District on June 30, 1952.

In addition, the following listed published and unpublished reports were reviewed during the investigation, and certain information and data presented therein were used in the preparation of this bulletin.

"Ventura County Investigation", Bulletin No. 46, Division of Water Resources, California State Department of Public Works. 1933.

"Ventura County Investigation, Basic Data for the Period 1927 to 1932, Inclusive", Bulletin No. 46-A, Division of Water Resources, California State Department of Public Works.

"Future Water Supply for Ventura, California", J. B. Lippincott. May, 1934.

"Report on Survey of Ventura River, California, for Flood Control", War Department, United States Engineer Office. October 15, 1940.

"Change in Ground Water Elevation in Various Pumping Areas, Ventura County, California, 1928 to 1941", Richard H. Jamison. Transaction of 1942 of the American Geophysical Union.

"Survey Flood Control, Calleguas Creek, California", War Department, United States Engineer Office. December 23, 1942.

"Soil and Water Conservation Research Needs in the Simi Valley and Adjacent Areas, Ventura County, California", United States Department of Agriculture, Soil Conservation Service, Office of Research. February, 1944.

"Report on Survey of Santa Clara River, California, for Flood Control", War Department, United States Engineer Office. December 20, 1945.

- "Flood Control and Water Conservation, Ventura County Flood Control District, Zone One", Donald R. Warren Company. 1945.
- "Flood Control and Water Conservation, Ventura County Flood Control District, Zone Two", Donald R. Warren Company. 1945.
- "Flood Control and Water Conservation, Ventura County Flood Control District, Zone Three", Donald R. Warren Company. 1945.
- "Flood Control and Water Conservation, Ventura County Flood Control District, Zone Four", Donald R. Warren Company. 1946.
- "Water Supply of Santa Clara Water Conservation District", Harold Conkling. November 19, 1947.
- "Water Supply, Newhall Ranch", Harold Conkling. January, 1948.
- "Safe Yield - Matilija Reservoir", Harold Conkling. May, 1948.
- "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District", Harold Conkling. September, 1949.
- "Demand on Casitas Reservoir and Safe Yield", Harold Conkling. April, 1950.
- "Hydrology of Zone 3, Ventura County Flood Control District", Harold Conkling. June, 1950.
- "Exportation of Water from Piru Creek to Zone No. 3", Richard H. Jamison. August, 1951.
- "Water Resources of California", Bulletin No. 1, California State Water Resources Board. 1951.
- "Overdraft on the Deep Aquifer in Pleasant Valley and Possibilities of Recharge by Spreading", John F. Mann, Jr. July 3, 1952.
- "Report of Investigation and Recommendations for Acquisition and Construction of a Water Conservation System", United Water Conservation District of Ventura County, California. October, 1952.
- "Ground Water Replenishment by Penetration of Rainfall, Irrigation and Water Spreading in Zone 3, Ventura County Flood Control District, California", United States Department of Agriculture, Soil Conservation Service, Research Branch. April, 1953.

The Division of Water Resources is presently conducting surveys and studies for the State-Wide Water Resources Investigation, authorized by Chapter 1514, Statutes of 1945, as amended. This investigation, under direction of the State Water Resources Board, has as its objective the formulation of The California Water Plan for full conservation, control, and utilization of the

State's water resources to meet present and future water needs for all beneficial purposes and uses in all parts of the State, insofar as practicable. As a result of this investigation, the State Water Resources Board in May, 1951, published "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan". Included as an integral feature of these projects is a diversion conduit to deliver supplemental water to Ventura County. These projects were authorized and adopted by the 1951 Legislature in Chapter 1441, Statutes of 1951. Under this authorization, provision was made for the construction of works, operation, and maintenance thereof by the Water Project Authority of the State of California. Financing the construction of works was provided for in the authorizing act through the issuance and sale of revenue bonds and through receipt of contributions from other sources. The Division of Water Resources, since 1951, has been continuing investigations, studies, and surveys preparatory to construction of works, through budgetary appropriation by the Legislature.

#### Cooperation With Other Agencies

In addition to cooperation extended to the Division of Water Resources in obtaining and utilizing basic data and information as acknowledged hereinbefore, certain phases of the investigation were conducted under programs of mutual cooperation with other agencies then engaged in analyzing water resources problems in various portions of Ventura County. These cooperative programs resulted in prevention of duplication of effort, and permitted a more detailed analysis to be made of the affected areas.

An agreement, entitled "Memorandum of Understanding with Reference to Water Resources Investigation of Ventura County", was entered into on April 23, 1951, by the Division of Water Resources, United Water Conservation District, and Ventura County Flood Control District. The objective of this agreement was to coordinate the work of the three agencies involved in the investigation of the water



problems of the Santa Clara River Valley. Copies of the memorandum of understanding, and supplements thereto entered into by the same agencies on October 1, 1952, and November, 1952, are included in Appendix A.

In order to provide certain necessary basic data relating to dam and reservoir sites on tributaries of the Santa Clara River, prior to commencement of field work by the Division of Water Resources on July 1, 1951, a service agreement was entered into between the Ventura County Flood Control District and the Division of Water Resources on April 24, 1951, wherein the District was to procure and provide the Division with these data and be reimbursed therefor by the Division in an amount not to exceed \$1,500. The terms of this agreement were executed, and the District was subsequently reimbursed in the amount of \$1,500.

During the course of the investigation, a cooperative hydrographic program was carried on by the Ventura County Water Survey, United Water Conservation District, Santa Clara Water Conservation District, United States Geological Survey, and Division of Water Resources. This program included measurements of flood flow and rising water at selected points on various watercourses throughout the County, together with maintenance of stream gaging stations.

The United States Department of Agriculture, Soil Conservation Service, Research Branch, under terms of a cooperative agreement with the Ventura County Flood Control District, entered into on November 1, 1950, conducted a study of ground water replenishment by penetration of rainfall, irrigation, and water spreading in Ventura County Flood Control District, Zone 3. The Division of Water Resources extended cooperation to the Soil Conservation Service by supplying basic hydrologic data and results of a geological investigation of the area under consideration, including the location and extent of ground water aquifers and of substrata which might impede or prevent the downward movement of waters spread on the ground surface. The results of the Soil Conservation Service study are contained in a report entitled "Ground Water Replenishment by Penetration of Rainfall, Irrigation,

and Water Spreading in Zone 3, Ventura County Flood Control District, California, April, 1953". Certain data contained in this report were utilized in the Ventura County Investigation.

### Scope of Investigation and Report

It has been stated that under provisions of the authorizing agreements the general objectives of the Ventura County Investigation included analysis of the quality, replenishment, and utilization of the underground water supplies of the County, and the preparation of preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent. Achievement of these objectives necessitated a comprehensive investigation, the scope of which included full consideration of surface as well as ground water supplies, and the evaluation of present and probable ultimate water utilization and supplemental water requirements. Field work in the investigational area and office studies, as authorized by the initial and supplemental cooperative agreements, commenced on July 1, 1951, and continued into 1953.

In the course of the field investigation, available precipitation and stream flow records were collected and compiled for the purpose of evaluating water supplies of the County. Four stream gaging stations equipped with automatic water stage recorders were installed and maintained to supplement hydrographic data available from 15 gaging stations maintained by the Ventura County Water Survey and the United States Geological Survey. These stations were on Tapo Creek at Walnut Road in Simi Valley, Calleguas Creek at Camarillo State Hospital Bridge, and on Calleguas Creek at Highway 101 (later moved to Conejo Creek immediately above its confluence with Calleguas Creek). A station established in 1951 on San Antonio Creek, immediately below the point of outflow from Ojai Valley, was destroyed during the storm of January 15, 1952, and was not replaced. In addition, 40 stations equipped with staff gages or datum reference points were established and maintained for varying periods of time on many minor watercourses throughout the County. Frequent



stream flow discharge measurements were made not only at all gaging stations, but also throughout selected reaches of major streams for the purpose of determining percolation rates therein. Periodic measurements were also made along the Santa Clara River at points of rising water.

Investigation was made of geologic features of ground water basins of the County, including storage capacity and the occurrence and movement of ground waters therein. In this connection, 1,534 water well logs and 138 oil well logs were collected and analyzed. The report on the geologic investigation is included as Appendix B.

The attempt was made to locate in the field all operating and nonoperating water wells in the County. Monthly measurements of ground water levels at 974 selected wells, made by the Ventura County Water Survey since 1949, together with seasonal measurements available from 1933, were utilized to determine the effects of draft on and replenishment of the ground water basins. Supplemental measurements were made by the Division of Water Resources at wells in certain critical areas in the fall of 1951 and in the spring of 1952. A continuous record of ground water level fluctuations in the Santa Clara River Valley and in the Oxnard Plain-Pleasant Valley area was available from about 25 water stage recorders, maintained for many years by the Santa Clara Water Conservation District. The Division of Water Resources supplemented these records by maintaining water stage recorders, for varying periods of time, at 27 nonoperating water wells in selected areas.

The nature and extent of present land use was determined from a survey conducted in the developed areas of Ventura County during 1949 and 1950 in connection with the aforementioned State-Wide Water Resources Investigation. A field check of the results of this survey was made in 1951 as a part of the Ventura County Investigation. The results of the land use surveys were used in conjunction with water use data to determine present water requirements.

As an aid in estimating future water requirements, a land classification

survey was conducted in 1952, wherein all lands not then urbanized were classified with regard to their suitability for irrigated agriculture. In addition, lands not considered susceptible to irrigation were surveyed in the field to ascertain their potential for urban and suburban developments.

Current irrigation practices in the County were studied in order to determine unit application of water to important crops on lands of various soil types, and the influence of climatic factors thereon. Water use data collected from mutual water companies and certain large ranches included records of pump discharge, acreages served, crops irrigated, and amounts of water applied. Estimates of total ground water extractions from confined aquifers of the Santa Clara River coastal plain and adjacent areas were made for each of the seasons from 1944-45 through 1951-52. These estimates were based upon records of power consumption and pump test results supplied by the Southern California Edison Company.

Studies were made of the mineral quality of surface and ground waters, in order to evaluate their suitability for beneficial use and to determine the cause of any degradation thereof. In this connection, 1,080 partial and 542 complete mineral analyses were made of ground waters, and 156 partial and 234 complete analyses were made of surface waters. In addition, in excess of 600 complete analyses of surface and ground water supplies, dating back to 1927, obtained from Fruit Growers Laboratory Inc., Santa Clara Water Conservation District, Ventura County Farm Advisor, and Division of Water Resources Bulletin No. 46, were studied. A detailed report on the quality of surface and ground water supplies of Ventura County is scheduled for publication by the Division of Water Resources in the latter part of 1953.

Detailed hydrologic studies were made for each of the principal stream systems of the County. These studies included determination of present developed safe yield of surface and ground water supplies, present and probable future supplemental water requirements, present waste to the ocean of surface and ground

waters, and of the portion of this waste susceptible to conservation both by surface and underground reservoirs.

The development of possible plans for additional conservation of local water supplies included field examination of feasible dam sites, together with a geologic investigation thereof. Preliminary designs and estimates of cost were prepared for several heights of dam at many of the sites, and of conveyance and distribution systems, and appurtenant works.

Preliminary plans and estimates of cost were also prepared of works for furnishing supplemental water from the proposed Southern California Diversion Conduit of the Feather River Project and from the Colorado River supply of the Metropolitan Water District of Southern California. Consideration was given to the financial and organizational aspects attendant on the development of local and imported water supplies.

Results of the Ventura County Investigation are presented in this report in the four ensuing chapters. Chapter II, "Water Supply", contains evaluations of precipitation, surface and subsurface inflow and outflow, and imports of water. It also includes results of investigation and study of underground hydrology, and sets forth estimates of present developed safe yield of surface and ground water supplies. Data regarding the mineral quality of surface and ground water supplies are presented therein. Chapter III, "Water Utilization and Requirements", includes data and estimates of present and probable ultimate land use and water requirements, and contains estimates of present and probable ultimate supplemental water requirements. It also includes available data on demands for water with respect to rates, times, and places of delivery. Chapter IV, "Plans for Water Supply Development", describes preliminary plans for conservation and utilization of local water supplies, including operation and yield studies, design considerations and criteria, and estimates of cost for the construction of works. Similar consideration is given to the development of imported water supplies. Chapter V, "Summary of Conclusions, and Recommendations",



includes a brief summary of conclusions drawn from the first four chapters and recommendations resulting therefrom.

### Area Under Investigation

The area under investigation comprises all lands within the boundaries of Ventura County, with the exception of Anacapa and San Nicolas Islands. Ensuing discussions of the County refer to the mainland area only. In addition, proper analysis of the available water supply necessitated investigation of that portion of the drainage area of the Santa Clara River lying within Los Angeles County.

Ventura County is situated in the South Coastal Area of California, and adjoins Santa Barbara County on the west, Los Angeles County on the east and south, and Kern County on the north. It is bounded on the southwest by the Pacific Ocean, with its coastal frontage extending northwesterly about 40 miles from the Los Angeles county line to Santa Barbara County. Ventura County has an average north and south dimension of about 50 miles, and an average width in an east and west direction of about 40 miles. The mainland portion has an area of 1,857 square miles. The location of the County is shown on Plate 1, "Location of Ventura County".

### Drainage Basins

Ventura County is characterized by rugged mountainous terrain covering the northerly portion of its area, with most present developments concentrated in the alluvial valleys and lower rolling topography found in the southerly portion. The mountainous area is comprised of the Santa Ynez, Topatopa, and Piru Mountains, which are segments of the Transverse Range of the coastal ranges of California, as are the Santa Monica Mountains found in the southeasterly portion of the County. Numerous ridges in the foregoing mountains extend to elevations in excess of 6,000 feet, attaining a maximum elevation of 8,826 feet at Mt. Pinos at the northerly county boundary.

The County is drained by four principal stream systems, namely Ventura

River, Santa Clara River, Calleguas Creek, and Cuyama River. With exception of the Cuyama River, these streams discharge into the ocean along the coastal front forming the southwesterly county boundary. Minor areas in the westerly, northerly, and southeasterly portions of the County drain into Santa Barbara, Kern, and Los Angeles Counties, respectively. Furthermore, in several instances, small areas of the foregoing counties are drained by streams which are otherwise entirely within Ventura County. The headwaters of the Cuyama River rise in the northwesterly portion of the County and thence drain north and west to discharge into the ocean through the Santa Maria River. In addition to the foregoing principal streams, there are many minor watercourses and drainage systems, the largest being Malibu Creek, which drains the southerly portion of the County.

The drainage area of the Ventura River comprises 226 square miles, of which 194 square miles are designated mountains and foothills, and 32 square miles valley and mesa lands. Elevations in the drainage area vary from a maximum of 6,003 feet above sea level at Monte Arido in the northwesterly extremity of the watershed, to sea level at the mouth of the river. The mean seasonal natural runoff of the Ventura River at its mouth has been estimated to be about 67,800 acre-feet. Present developments are concentrated in the small alluvial valleys and adjacent hills south and east of the confluence of Matilija and North Fork Matilija Creeks, which are the principal tributaries of the Ventura River.

The Santa Clara River drains an area above its mouth of 1,605 square miles, of which 1,455 square miles are designated mountains and foothills, and 150 square miles valley and mesa lands. The river flows generally in a southwesterly direction from its headwaters in Los Angeles County, at elevations in excess of 5,000 feet, to the Pacific Ocean near Oxnard. Its principal tributaries are Sespe Creek with a drainage area of about 254 square miles above the gage near Fillmore, and Piru Creek with a drainage area of about 432 miles above the gage near Piru, both of which flow easterly and then southerly to join the main stream near the



towns of Fillmore and Piru, respectively. Another important tributary, Santa Paula Creek, drains an area of 40 square miles southwesterly of the Sespe Creek watershed and, flowing generally south, has its confluence with the Santa Clara River at the town of Santa Paula. Urban and agricultural developments are found along the Santa Clara River bottomlands and on the broad coastal plain at its mouth. The drainage areas of Sespe, Piru, and Santa Paula Creeks are comprised primarily of national forest lands, wherein few developments prevail. The mean seasonal natural runoff of the Santa Clara River at its mouth is estimated to be about 216,400 acre-feet.

The headwaters of Calleguas Creek and its principal tributary, Conejo Creek, originate in the Santa Susana and Santa Monica Mountains at elevations in excess of 3,000 feet. The drainage area, poorly defined in the lower reaches of the stream, comprises about 331 square miles. Oak Ridge, a relatively narrow elongated range of hills extending in a east-west direction, separates the Calleguas Creek watershed from that of the Santa Clara River on the north. The watershed is defined by the Santa Susana Mountains on the east and by the Santa Monica Mountains on the south. The system drains generally in a southwesterly direction, and discharges into the ocean through Mugu Lagoon about seven and one-half miles southeasterly of Port Hueneme. The drainage area is characterized by a more moderate relief than that of the Ventura and Santa Clara River watersheds, with most of the area lying below 1,000 feet in elevation. Present urban and agricultural developments occur in the relatively small alluvial valleys and adjacent hills throughout the area, and on the coastal plain across which Calleguas Creek flows in its lowermost reaches. The mean seasonal natural runoff of Calleguas Creek is estimated to be about 15,200 acre-feet.

The southerly slopes of the Santa Monica Mountains within Ventura County are drained by Las Virgenes and Triunfo Creeks, tributaries of Malibu Creek, together with several minor streams discharging directly into the ocean. Runoff from

these streams is small and developments within their drainage areas are of a minor nature.

### Climate

The Mediterranean type of climate typical of the South Coastal Area prevails in Ventura County, with proximity to the ocean providing a moderating effect on climatic conditions throughout the developed area. A long, dry, warm summer season is followed by a shorter wet winter period accompanied by cooler temperatures. In excess of 80 per cent of the mean seasonal precipitation occurs during the months of December through March. Precipitation occurs generally in the form of rainfall, except in the mountainous regions where there is some snowfall in most years. Fog is prevalent along the coast during portions of each year. Temperature extremes generally increase with elevation and distance from the coast. The growing season, or lapse of time between killing frosts, is long, and generally decreases with elevation and distance from the coast. Since killing frosts on the coastal plain of the Santa Clara River Valley are extremely rare, portions of this area are producing as many as three crops per year.

Certain pertinent climatological data for three selected stations in Ventura County are shown in the following tabulation:

Station	: : Elevation, : in feet :	: : Recorded : temperature, : in degrees F. : Max- : Min- : Av- : imum : imum : erage	: : Mean seasonal : precipitation, in : inches of depth :	: : Average : number of : days between : killing frosts
Ojai	750	119 13 61	18.76	232
Oxnard	51	99 29 59	14.47	332
Santa Paula	275	105 27 --	17.50	277

### Geology

Ventura County lies within the Transverse Ranges Geomorphic Province of California. Formations present include igneous and metamorphic rocks of pre-Cretaceous age, marine and continental sediments of Cretaceous to Recent age, and



volcanic rocks of Tertiary age. With exception of the Recent stream deposits, all formations are to some extent deformed. In general, the structures, including fold axes and faults, trend in an east-west direction.

Ground water occurs to some extent in all of the foregoing formations.

The principal aquifers are composed of continental and marine sediments of Recent and Pleistocene age. In certain areas, wells are supplied from fractured volcanic rocks of the Tertiary system, or from fissures in crystalline or consolidated rocks of pre-Quaternary age. The fractured rocks generally yield little water. However, in some localities this source constitutes the entire water supply. A detailed geologic report is included as Appendix B.

### Soils

Soils of Ventura County vary markedly as to type, composition, depth, and other physical and chemical properties, in accordance with origin of the parent material, nature of deposition, and age and degree of development since the time of deposition. In general, the soils can be divided into three broad groups: (1) residual soils, which have been developed in place from the disintegration and weathering of consolidated rocks, both of sedimentary and basic igneous origin; (2) old valley filling and coastal plain soils, which are derived from elevated, unconsolidated water-laid deposits which have undergone marked changes since their deposition; and (3) recent alluvial soils, which are derived from sediments that have undergone little or no change or internal modification since their deposition. These soils have their origin in a variety of materials, including shale, sandstone, conglomerate, basic igneous rocks, and old valley filling deposits.

Residual soils are identified with hill and mountainous areas. Soil textures vary from medium to heavy; and soil depth, although variable, is generally shallow, containing inclusions of rock outcrop throughout most of the areal extent of the group. Drainage is generally good. Moisture retention is adequate except where the underlying bedrock is near the surface. Residual soils comprise a



relatively small area, occupying the rolling hills and ridges at the perimeter of the interior valleys.

Soils of the old valley filling and coastal plain groups have a varied topography, occurring both on hill and rolling lands and on smooth and eroded marine or stream terraces. They also occur on sloping remnants of old alluvial fans that have either been elevated since time of deposition, or have been left in their present position through the cutting of deeper stream channels or valleys through them. The soils are usually intermediate in elevation between the residual and recent alluvial groups. They have medium texture with friable surface composition, and are well suited to irrigated agriculture. Subsoils are somewhat more compact and heavier in texture, with local tendencies toward hardpan. Surface drainage is generally good, but subsurface drainage is in some cases retarded by the heavy compact nature of the subsoil. No indication of the accumulation of harmful salts in the soil solution has been noted as a result of this condition. In portions of the County, particularly along the northern and eastern sides of Ojai Valley, this group contains considerable rock outcropping.

Topography identified with the recent alluvial soils is smooth and gently sloping. This group covers nearly the entire coastal plain of the Santa Clara River Valley, and also occurs as river and creek bottom deposits along the Santa Clara River and its tributaries. These soils comprise the numerous alluvial fans found at the mouths of tributary creeks throughout the County. Depth of soil is generally good, with textures grading from light to very heavy. The soils of the group have the common characteristic of stratification in the subsoil. On all alluvial fans, both surface and internal drainage is good. However, in some of the lower valleys where the soils are quite heavy, drainage is poor, as in the southerly portion of the coastal plain and extending northerly therefrom toward Camarillo. An extensive drainage system has been constructed in this area to alleviate this problem. In portions of the coastal plain, where drainage works have not been constructed, there are heavy concentrations of soluble salts in the soil solution.

Recent alluvial soils comprise the largest area in the County presently developed to either irrigated agriculture or developments of an urban nature.

#### Present Development

The establishment of Mission San Buenaventura in 1782 by Franciscan Father Junipero Serra marked the beginning of the development of Ventura County. After California became a state in 1850, and until legislative action in 1872, the area now included within Ventura County was part of Santa Barbara County.

Early-day activities were of an agricultural nature and devoted to the sustenance of the mission settlement. Water supplies for the mission were obtained by diversion from the Ventura River. Portions of the original aqueduct and receiving reservoir, used for domestic and minor irrigation purposes, are still intact. In common with other portions of Spanish California, Ventura County, in the early 19th century, was divided into several large land grants, known as ranchos. The principal activity of the "rancheros" was the raising of cattle, sheep, horses, and mules on extensive pasture lands. After the acquisition of California by the United States and the accompanying decline of the ranchos, extensive plantings were made of wheat, barley, corn, and other dry-farmed crops.

During the decade from 1880 to 1890, the economy of Ventura County experienced a marked change with the introduction of large-scale irrigation in areas where water supplies were readily available. The original plantings of citrus and walnuts were made about this time in Ojai Valley and along the Santa Clara River. These crops, particularly the former, have continued to have great commercial importance to the present day. Beans were introduced to the Oxnard Plain just prior to the turn of the century. The subsequent rapid expansion of this crop has resulted in the designation of the Oxnard Plain as the "bean basket of the world".

Originally, irrigation was accomplished through diversion of surface waters. However, increased water utilization, coupled with protracted periods of drought wherein flow in Ventura County streams diminished to negligible proportions



during the summer and fall, caused irrigators to turn to utilization of supplies available in underlying ground water basins. At first centrifugal pumps were employed, but later declining water levels necessitated the installation of deep-well turbine pumps throughout most of the irrigated areas.

At the present time the Santa Clara River Valley, the coastal plain, and portions of the Ventura River and Calleguas Creek drainage areas are extensively developed to irrigated agriculture. However, irrigation developments in many parts of the County have been impeded through lack of firm water supplies. Land use surveys conducted in Ventura County during 1949-50 indicated that there were, at that time, in excess of 109,000 net acres of irrigated land. Leading crops were citrus with about 43,000 acres, beans with about 33,000 acres, and walnuts with slightly less than 18,000 acres. The value of crops produced in Ventura County in 1950 was in excess of \$50,000,000, as compared to a reported value of about \$20,000,000 in 1940.

At the present time and for many years past, the oil industry has been a leading producer of revenue. Large areas are presently devoted to oil fields and appurtenant developments. Numerous active oil seeps in various portions of the County attracted oil prospectors as early as the middle of the 19th century.

Other principal industries in Ventura County, excluding those allied with the production of oil, are citrus packing and vegetable processing. The American Crystal Sugar Company's sugar beet processing plant in Oxnard is the largest of the latter. Sand and gravel works supply local demands for aggregates. Concrete pipe, used in irrigation distribution and drainage systems, is manufactured locally. The United States Navy maintains a large advanced base depot at Port Hueneme, as well as an air missile test center at Point Mugu. A United States Air Force base is located near Camarillo. Electrical energy is brought into the County by the Southern California Edison Company.

The 1950 Federal census reported the population of Ventura County to be 114,647. From 1940 to 1950, the population increased by 44,962, or by about 65 per

cent of the reported 1940 total of 69,685. The City of Oxnard, which in 1940 ranked third in population of incorporated cities in the County, was first in 1950 with a population of 21,567. The population of other incorporated cities in 1950, in order of their magnitude, was: Ventura, 16,534; Santa Paula, 11,049; Fillmore, 3,884; Port Hueneme, 3,024; and Ojai, 2,519.

Ventura County is well served with rail, air, and highway transportation facilities. The coast route of the Southern Pacific Railroad passes through the County, as do U. S. Highways 101 and 399 and several state highways. Local products are exported by sea from Port Hueneme. In addition, offshore loading of oil tankers is effected by means of submarine pipe lines constructed from the oil fields in the vicinity of the City of Ventura.

Recreational facilities are available in county parks, beaches, and in the Los Padres National Forest. Ojai Valley is a noted southern California resort area.

The assessed valuation of Ventura County in the fiscal year 1952-53, as reported by the County Auditor, was \$283,230,490. Ventura County is among the top quarter of counties in California from the standpoint of assessed valuation.

Water service is provided through individual effort, by municipal and other public agencies, and by many private agencies. In addition, many public districts have been formed to deal with the problems of water supply, flood control, drainage, and land reclamation. The activities of these districts, their powers, and purposes are described in Appendix D. The boundaries of the Ventura County Flood Control District, the Santa Clara Water Conservation District, the United Water Conservation District, the Ventura Municipal Water District, and the Simi Valley Water Conservation District are delineated on Plate 2, entitled "Major Water Districts, 1953".

#### Hydrologic Units

In order to facilitate analysis of present and probable future water

supply problems of Ventura County, the southerly portion thereof has been divided into four hydrologic units. These units, the boundaries of which are shown on Plate 3, "Hydrologic Units", have been designated "Ventura", "Santa Clara River", "Calleguas-Conejo", and "Malibu".

Boundaries of the hydrologic units were defined after giving consideration to those factors of water supply and utilization, topography, and geology, which affect hydrologic analysis, and in order to include those lands having correlative water problems. In general, each unit extends to definite political or topographic boundaries. It will be noted on Plate 3 that the northerly limits of the Ventura and Santa Clara River Units conform generally to the boundary of the Los Padres National Forest, except in those instances where contiguous bodies of irrigable land encroach onto the federal reservation. The complex nature of the Ventura, Santa Clara River, and Calleguas-Conejo Units necessitated further division thereof into subunits, the boundaries of which are also shown on Plate 3. Table 1 presents the total area of each of the hydrologic units and subunits.



TABLE 1  
AREAS OF HYDROLOGIC UNITS AND SUBUNITS

Name	:	Acres
Ventura		
Upper Ojai		9,670
Ojai		10,800
Upper Ventura River		25,990
Lower Ventura River		31,170
Rincon		15,390
Subtotal		<u>93,020</u>
Santa Clara River		
Eastern		2,800
Piru		47,310
Fillmore		45,450
Santa Paula		52,040
Mound		17,490
Oxnard Forebay		6,170
Oxnard Plain		46,460
Pleasant Valley		36,010
Subtotal		<u>253,730</u>
Calleguas-Conejo		
Simi		50,010
East Las Posas		52,480
West Las Posas		14,160
Conejo		28,930
Tierra Rejada		4,390
Santa Rosa		8,030
Subtotal		<u>158,000</u>
Malibu		<u>52,670</u>
TOTAL		<u>557,420</u>

There are certain other relatively small areas of Ventura County which, although largely undeveloped, are by virtue of their soils and topography susceptible to future irrigation development. These areas are located primarily in the northerly portion, in the upper reaches of Piru Creek and the Cuyama River. In addition, certain lands included within the Los Padres National Forest, other than those included within the aforementioned hydrologic units, either presently use small amounts of water or are considered to have a small potential water requirement.



## CHAPTER II. WATER SUPPLY

The principal sources of water supply of Ventura County are direct precipitation and runoff from tributary drainage areas. A small import of Santa Clara River water from Los Angeles County, together with relatively minor quantities of water released from the Los Angeles Aqueduct in the upper reaches of the Santa Clara River watershed have contributed to the supply. So far as was determined during the investigation, there is no record of export of water from Ventura County. The water supply of the County is considered and evaluated in this chapter under the general headings: "Precipitation", "Runoff", "Underground Hydrology", "Quality of Water", and "Safe Yield of Presently Developed Water Supply". The following terms are used as defined in connection with the discussion of water supply in this report:

Annual - This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year".

Seasonal - This refers to any 12-month period other than the calendar year.

Precipitation Season - The 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season - The 12-month period from October 1st of a given year through September 30th of the following year.

Investigational Seasons - The two runoff seasons of 1951-52 and 1952-53, during which most of the field work of the Ventura County Investigation was performed.

Mean Period - A period chosen to represent conditions of water supply and climate over a long series of years.

Base Period - A period chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate were approximately equivalent to mean conditions, and because adequate data for such hydrologic analysis were available.

Mean - This is used in reference to arithmetical averages relating to mean periods.

Average - This is used in reference to arithmetical averages relating to periods other than mean periods.

In studies for the current State-Wide Water Resources Investigation, it was determined that the 50 years from 1897-98 to 1946-47, inclusive, constituted the most satisfactory period for estimating mean seasonal precipitation generally throughout California. Similarly, the 53-year period from 1894-95 to 1946-47, inclusive, was selected for determining mean seasonal runoff. In studies for the Ventura County Investigation, conditions during these periods were considered representative of mean conditions of water supply and climate.

Studies were made to select a base period for hydrologic analysis of Ventura County during which conditions of water supply and climate would approximate mean conditions, and for which adequate data on water supply, water utilization, and ground water conditions would be available. It was determined that the 15-year period from 1936-37 through 1950-51 was the most satisfactory in this respect. The average seasonal water supply during this chosen base period so closely approached that of the mean period throughout the County that its magni-



tude was considered to be equivalent to that of the mean period. Furthermore, the base period exemplifies the historic cyclic nature of the water supply of Ventura County. It includes a series of eight years from 1936-37 through 1943-44 wherein the average seasonal water supply substantially exceeded that of the mean period, followed by a series of seven years wherein the average seasonal water supply was considerably less than that of the mean period. Accordingly, these periods are hereinafter referred to as the "wet period" and "drought period", respectively.

Water resources problems of Ventura County stem in part from the erratic and apparently cyclic occurrence of its water supply. The relationship between water supply and utilization during drought periods establishes the magnitude of these problems. Since 1894 there have been three major drought periods, namely: 1894-95 through 1903-04; 1922-23 through 1935-36; and 1944-45 through 1950-51. Water supply data are almost entirely estimated for the earliest of these periods, and partially so for the period from 1922-23 through 1935-36. Fairly reliable data are available throughout the County for the drought period included in the chosen base period. Although for study purposes, this latter period has been adopted as representative of drought conditions in Ventura County, it has been concluded that in some portions of the County, the period from 1922-23 through 1935-36 was of somewhat greater severity in regard to accumulated deficiency in water supply. The results of certain studies presented later in this bulletin should be qualified accordingly.

## Precipitation

Ventura County receives a substantial portion of its precipitation from storms originating in both the West and Northwest Pacific and in the Southwest Pacific, almost entirely during winter months. Precipitation, comprising the largest item of the County's water supply, is consumed or disposed of in various ways: evaporation from plant and ground surfaces soon after the occurrence of rain; through accretion to the depleted soil moisture of the soil mantle, which source subsequently furnishes water to meet consumptive requirements of vegetal cover; through deep percolation to ground water in absorptive areas; and through surface runoff.

### Precipitation Stations and Records

During the investigational seasons there were 57 precipitation stations in operation in Ventura County. Five of these stations were equipped with continuous recorders, and the remainder with non-recording type gages which were usually read daily. In addition, there have been some 50 precipitation stations in operation in Ventura County for varying lengths of time, which are now inactive. The longest record is that of the station at Ventura, which extends back to 1873. The stations are numerous and well distributed over the southerly portion of the County, but in the northerly and less accessible mountainous regions few stations have been established and the precipitation pattern therein is less susceptible to reliable determination.

Locations of the precipitation stations within and adjacent to Ventura County are shown on Plate 4, "Lines of Equal Mean Seasonal

precipitation". Map reference numbers correspond to those presented in State Water Resources Board Bulletin No. 1, "Water Resources of California". For those stations not appearing in Bulletin No. 1, numbers were assigned consecutively after the last number presented in that bulletin. Thirty-nine active precipitation stations in Ventura County having unbroken records of 15 years or longer as of 1950-51 are listed in Table 2, together with the map reference number, elevation, period and source of record, mean, maximum, and minimum seasonal depth of precipitation for each.

TABLE 2

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT  
SELECTED STATIONS IN VENTURA COUNTY

Map reference: number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation inches of depth
3-83	Ozena	3,700	1904-05 1951-52	USWB	13.40	1940-41 32.60 1948-49 4.64
4-60	Aggen Ranch	375	1903-04 1951-52	Private	15.00	1940-41 32.48 1947-48 6.21
4-31	Bardsdale	400	1932-33 1951-52	Private	17.45	1940-41 39.58 1947-48 8.65
4-53	Borgstroms Ranch	200	1921-22 1951-52	Private	14.82	1940-41 35.40 1923-24 6.14
4-39	Camulos Ranch Headquarters	730	1928-29 1951-52	Private	14.25	1940-41 36.30 1947-48 7.78
4-22	Canada Larga	800	1934-35 1951-52	Private	17.90	1940-41 43.62 1947-48 8.83
4-16	Casitas Ranch	400	1924-25 1951-52	Private	23.81	1940-41 48.02 1947-48 10.90
4-65	Conejo Ranch	650	1913-14 1951-52	Private	15.38	1940-41 33.82 1947-48 6.03



TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT  
SELECTED STATIONS IN VENTURA COUNTY

Map reference: number :	Station	Elevation, in feet :	Period of record :	Source of record :	Estimated mean seasonal precipitation, in inches of depth :	Maximum and minimum seasonal precipitation inches of depth :
4-54	Del Mar Ranch	300	1924-25 1951-52	Private	16.82	1940-41 41.75 1947-48 7.40
4-23	Dennisons	1,250	1883-84 1951-52	Private	21.92	1883-84 60.02 1950-51 6.62
4-63	Epworth	800	1927-28 1951-52	Private	16.40	1940-41 34.36 1947-48 6.90
4-33	Fillmore (Citrus Association)	500	1925-26 1951-52	Private	18.60	1940-41 38.68 1947-48 8.82
4-24	Krotona	830	1928-29 1951-52	Private	19.97	1940-41 45.17 1947-48 9.49
4-36	Levens and Goodenough Ranch	550	1931-32 1951-52	Private	17.00	1940-41 38.43 1947-48 8.07
4-58	Limoneira Ranch	335	1904-05 1951-52	Private	16.66	1940-41 38.51 1923-24 7.13
4-18	Matilija Canyon	950	1902-03 1951-52	Private	24.76	1913-14 50.75 1918-19 6.88

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT  
SELECTED STATIONS IN VENTURA COUNTY

Map reference: number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation inches of depth
4-64	Moorpark	500	1916-17 1951-52	Private	14.12	1940-41 1923-24 30.99 5.55
4-40	Newhall Ranch	750	1912-13 1951-52	Private	17.33	1940-41 1947-48 37.12 7.84
4-601	Ojai, Mallory	750	1891-92 1951-52	Private	18.76	1940-41 1893-94 42.10 6.96
4-21	Ojai	800	1905-06 1951-52	Private	23.4	1940-41 1923-24 45.18 7.30
4-56	Oxnard	51	1898-99 1951-52	USWB	14.47	1940-41 1923-24 38.17 5.83
4-29	Pine Tree Ranch	400	1931-32 1951-52	Private	17.33	1940-41 1950-51 38.73 8.61
4-38	Piru (Citrus Association)	650	1926-27 1951-52	Private	17.93	1940-41 1947-48 38.47 8.05
4-191	Port Hueneme Lighthouse	10	1891-92 1951-52	Private	13.79*	1940-41 1897-98 32.99 3.93

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT  
SELECTED STATIONS IN VENTURA COUNTY

Map reference: number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation inches of depth
4-26	Rancho La Cuesta	900	1930-31 1951-52	Private	21.93	1940-41 45.44 1950-51 9.14
4-17	Rancho Matilija	650	1925-26 1951-52	Private	21.85	1940-41 44.51 1947-48 8.96
4-30	Rancho Sespe	430	1906-07 1951-52	Private	18.67	1940-41 38.60 1923-24 8.80
4-27	Santa Paula	275	1897-98 1951-52	BI Co.	17.50	1940-41 38.11 1897-98 5.91
4-28	Santa Paula	290	1931-32 1951-52	CFA	16.48	1940-41 35.54 1950-51 8.41
4-62	Santa Rosa Valley No. 1	375	1929-30 1950-51	Private	12.47	1940-41 29.12 1947-48 4.79
4-0402	Saticoy (Culbertson Lemon Association)	150	1936-37 1951-52	Private	14.6	1940-41 35.34 1947-48 6.37
4-15	Selby Ranch	750	1921-22 1951-52	Private	21.86	1940-41 51.20 1924-25 8.00

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT  
SELECTED STATIONS IN VENTURA COUNTY

Map reference: number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation inches of depth
4-68	Simi Valley	1,200	1931-32 1951-52	Private	18.52	1940-41 40.46 1947-48 7.64
4-61	Snyder Ranch	300	1892-93 1951-52	Private	14.28*	1940-41 32.83 1897-98 4.26
4-59	Springville Ranch	60	1902-03 1951-52	ACS Co.	13.52	1940-41 33.41 1947-48 5.50
4-66	Tapo Mutual Water Company	1,080	1923-24 1951-52	TMW Co.	15.02	1940-41 34.83 1923-24 6.45
4-600	Thacher School	1,360	1906-07 1950-51	Private	22.0	1940-41 52.75 1923-24 7.31
4-5	Upper Sespe Creek	4,000	1927-28 1951-52	Private	25.34	1940-41 60.63 1950-51 9.12
4-52	Ventura	50	1873-74 1951-52	USWB	15.59	1940-41 36.71 1876-77 5.22

ACS Co. American Crystal Sugar Company  
BI Co. Blanchard Investment Company

CFA Ventura County Farm Advisor  
TMW Co. Tapo Mutual Water Company  
USWB United States Weather Bureau

\* Recorded



## Precipitation Characteristics

Precipitation in Ventura County occurs primarily as rainfall, although light snowfall is not uncommon in the higher mountainous areas in the northerly portion of the County. Depth of precipitation generally increases from west to east in the southerly developed areas of the County, but decreases in this direction toward the north. Mean seasonal depth of precipitation varies from a maximum of about 32 inches in the Topatopa Mountains to a minimum of about 12 inches in the vicinity of Point Mugu. Storms moving in from the West and Northwest Pacific are first intercepted by the mountains defining the watersheds of Ventura River, Santa Paula Creek, and Sespe Creek; and it is in the higher elevations of these watersheds that depth of precipitation is the greatest in the County. The Piru Creek watershed and that of the Santa Clara River above the Los Angeles County line receive less precipitation, since many of the more productive storms have been dissipated prior to reaching these areas. The light mean seasonal depth of precipitation in the Calleguas Creek drainage area, varying from about 12 to 18 inches, results from the relatively low elevation of the watershed and its position beyond the path of the principal storms.

Plate 4 depicts the variation in mean seasonal depth of precipitation over the County and in tributary watersheds. In certain instances, the preparation of Plate 4 required extension of incomplete or broken records through correlation with stations having long-term records.

Table 3 presents recorded and estimated seasonal depth of precipitation at five selected stations in various portions of the

County, together with the "precipitation index" for each of the seasons shown. The term "precipitation index" refers to the ratio of the average depth of precipitation during a given period or season to the mean seasonal depth, expressed as a percentage.

TABLE 3

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND  
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-60		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Inches		Inches		Inches		Inches		Inches	
	Index	of depth	Index	of depth	Index	of depth	Index	of depth	Index	of depth
1873-1874	96	15.02	--	--	--	--	--	--	--	--
1874-1875	98	15.24	--	--	--	--	--	--	--	--
76	135	21.00	--	--	--	--	--	--	--	--
77	33	5.22	--	--	--	--	--	--	--	--
78	130	20.22	--	--	--	--	--	--	--	--
79	82	12.79	--	--	--	--	--	--	--	--
1879-1880	142	22.06	--	--	--	--	--	--	--	--
81	89	13.91	--	--	--	--	--	--	--	--
82	77	11.98	--	--	--	--	--	--	--	--
83	74	11.51	--	--	--	--	--	--	--	--
84	232	36.13	--	--	--	--	--	--	--	--
1884-1885	61	9.46	--	--	--	--	--	--	--	--
86	130	20.22	--	--	--	--	--	--	--	--
87	95	14.75	--	--	--	--	--	--	--	--
88	130	20.31	--	--	--	--	--	--	--	--
89	108	16.85	--	--	--	--	--	--	--	--
1889-1890	171	26.65	--	--	--	--	--	--	--	--
91	98	15.39	--	--	--	--	--	--	--	--
92	71	11.10	95	17.82	--	--	--	--	--	--
93	151	23.49	154	28.82	--	--	--	--	--	--

TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND  
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Inches	Index	Inches	Index	Inches	Index	Inches	Index	Inches	Index
	: of depth	: of depth	: of depth	: of depth	: of depth	: of depth	: of depth	: of depth	: of depth	: of depth
	: Index	: Index	: Index	: Index	: Index	: Index	: Index	: Index	: Index	: Index
1893-1894	41	6.39	37	6.96	--	--	--	--	--	--
1894-1895	97	15.13	107	19.99	--	--	--	--	--	--
96	63	9.90	66	12.33	--	--	--	--	--	--
97	102	15.89	104	19.59	--	--	--	--	--	--
98	38	5.94	105	19.61	34	5.91	28	4.12*	33	4.5*
99	59	9.13	47	8.80	42	7.40	79	11.57	43	6.0*
1899-1900	61	9.48	57	10.73	55	9.57	68	9.87	69	9.5*
01	90	14.05	98	18.34	92	16.09	90	13.01	91	12.5*
02	81	12.69	72	13.60	75	13.09	87	12.53	76	10.5*
03	104	16.26	86	16.21	105	18.40	117	16.91	105	14.5*
04	68	10.64	65	12.14	66	11.54	50	7.28	65	9.0*
1904-1905	156	24.30	155	29.07	139	24.26	126	18.27	138	19.0*
06	123	19.23	109	20.42	102	17.93	121	17.48	101	14.0*
07	149	23.25*	176	33.02	159	27.83	139	20.10	159	22.0*
08	111	17.31	94	17.67	83	14.58	109	15.79	83	11.5*
09	184	28.73	138	25.81	148	25.90	146	21.11	149	20.5*
1909-1910	102	15.93	91	17.02	80	13.94	90	13.08	76	10.5*
11	149	23.23	157	29.49	126	22.00	124	17.99	127	17.5*
12	88	13.73	64	12.08	64	11.14	69	10.05	62	8.5*
13	104	16.28	78	14.65	85	14.91	83	12.08	83	11.5*



TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND  
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-60		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	: In inches :		: In inches :		: In inches :		: In inches :		: In inches :	
	Index	of depth	Index	of depth	Index	of depth	Index	of depth	Index	of depth
1913-1914	171	26.71	183	34.42	166	28.98	128	18.51	150	20.67
1914-1915	137	21.40	114	21.46	132	23.12	133	19.23	138	19.02
16	117	18.19	128	23.98	132	23.05	115	16.62	97	13.33
17	124	19.29	118	22.15*	122	21.38	109	15.76	109	15.04
18	135	21.12	120	22.45	113	19.84	94	13.58	113	15.57
19	59	9.09	72	13.55*	71	12.41	70	10.10	73	10.11
1919-1920	63	9.82	79	14.76	81	14.24	64	9.33	85	11.75
21	87	13.51	76	14.34	99	17.28	72	10.47	68	9.34
22	123	19.21	108	20.20	121	21.10	103	14.96	127	17.53
23	85	13.31	84	15.83	85	14.93	73	10.57	62	8.53
24	44	6.85	37	6.99	44	7.71	40	5.83	39	5.36
1924-1925	59	9.03	58	10.88	57	10.01	62	8.96	66	9.15
26	99	15.52	101	19.02	94	16.41	114	16.54	133	18.37
27	108	16.79	127	23.78	133	23.32	111	16.09	118	16.28
28	76	11.83	70	13.14	64	11.15	73	10.54	87	12.05
29	63	9.85	68	12.69	77	13.48	71	10.32	75	10.34
1929-1930	67	10.56	65	12.12	70	12.26	76	11.03	76	10.53
31	81	12.76	76	14.34	80	14.00	82	11.86	93	12.80
32	118	18.32	131	24.54	118	20.60	114	16.46	115	15.91
33	56	8.73	56	10.43	64	11.21	77	11.10	83	11.50

TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND  
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	: In inches :		: In inches :		: In inches :		: In inches :		: In inches :	
	Index	of depth	Index	of depth	Index	of depth	Index	of depth	Index	of depth
1933-1934	76	11.77	71	13.24	85	14.95	71	10.21	74	10.28
1934-1935	113	17.59	103	19.25	121	21.22	130	18.75	125	17.24
	88	13.66	101	19.09	95	16.57	75	10.82	79	10.88
	37	23.23	140	26.33	151	26.49	156	22.56	167	23.09
	38	20.67	163	30.64	153	26.73	135	19.59	135	18.57
	39	13.94	68	12.80	82	14.34	92	13.29	82	11.35
1939-1940	76	11.88	84	15.69	85	14.88	107	15.42	110	15.28
	41	36.71	224	42.10	218	38.11	264	38.17	255	35.18
	42	12.77	86	16.25	81	14.19	86	12.43	80	11.05
	43	19.88	128	24.06	166	29.06	140	20.28	162	22.38
	44	18.02	117	22.03	139	24.37	156	22.56	155	21.42
1944-1945	78	12.13	93	17.52	92	16.04	74	10.66	89	12.22
	46	8.67	79	14.79	74	12.99	68	9.87	93	12.84
	47	8.98	78	14.56	82	14.33	83	12.09	94	12.98
	48	5.55	43	8.11	51	8.89*	42	6.13	45	6.17
	49	5.85	56	10.47	51	8.91*	52	7.48	52	7.11
1949-1950	63	9.94	80	14.98	75	13.07	78	11.41	75	10.36
	51	7.09	52	9.79	47	8.14	56	8.12	66	9.08*
	52	23.78	164	30.75	196	34.30	173	25.07	197	27.17*

TABEL 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND  
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	: In inches :		: In inches :		: In inches :		: In inches :		: In inches :	
	Index : of depth :	Index :	Index : of depth :	Index :	Index : of depth :	Index :	Index : of depth :	Index :	Index : of depth :	Index :
Average for 15-year base period, 1936- 37 through 1950-51	92	14.35	99	18.67	103	18.04	106	15.34	111	15.27
Mean for 50- year period, 1897-98 through 1946- 47	100	15.59	100	18.76	100	17.50	100	14.47	100	13.80
Average for period of record	99	15.50	98	18.34	99	17.25	98	14.26	104	14.30

\* Estimated.

Precipitation in Ventura County exhibits extreme monthly and seasonal variation, but generally with a proportionate consistency throughout the County in any given season. Seasonal depth of precipitation at Ojai has varied from a minimum of 37 per cent of the mean in 1893-94, when 6.96 inches were recorded, to a maximum of 224 per cent of the mean in 1940-41, when 42.10 inches were recorded. Similar extremes occurred at other long-term stations throughout the County. The erratic seasonal occurrence of precipitation in Ventura County is depicted graphically on Plate 5, entitled "Recorded Seasonal Precipitation at Ojai, 1891-92 through 1951-52". The apparent cyclic nature of the occurrence of precipitation at this station is shown on Plate 6, entitled "Accumulated Departure from Mean Seasonal Precipitation at Ojai, 1891-92 through 1951-52".

About 80 per cent of the seasonal precipitation in Ventura County occurs during the four-month period from December through March. It is not unusual, however, for one or more of these months to be extremely dry in a given season. The mean monthly distribution of precipitation at Santa Paula, which may be considered generally representative of the County in this respect, is presented in Table 4.



TABLE 4  
MEAN MONTHLY DISTRIBUTION OF  
PRECIPITATION AT SANTA PAULA

: Precipitation :			: Precipitation :		
Month	: In inches:	In per cent of:	Month	: In inches:	In per cent
	: of depth :	seasonal total:		: of depth :	of seasonal
	:	:		:	total
July	0.01	0.1	January	3.86	22.0
August	0.03	0.2	February	4.07	23.2
September	0.31	1.8	March	3.04	17.4
October	0.62	3.5	April	0.98	5.6
November	1.23	7.0	May	0.38	2.2
December	2.94	16.8	June	<u>0.03</u>	<u>0.2</u>
			TOTALS	17.50	100.0

#### Quantity of Precipitation

In certain of the absorptive areas of Ventura County, wherein precipitation constitutes a direct source of ground water replenishment, it was necessary to evaluate the total quantity of precipitation for the purpose of required hydrologic analysis. These absorptive areas included the Piru, Fillmore, Santa Paula, and Oxnard Forebay ground water basins, of the Santa Clara River Unit, and the Simi Basin of the Calleguas-Conejo Unit. The mean seasonal quantity of precipitation on these areas was estimated by plotting recorded or estimated mean seasonal depth of precipitation at stations in or near the basins on a suitable base map. Lines of equal mean seasonal precipitation, or isohyets, were then drawn, as shown on Plate 4.

By planimetering the areas between these isohyets, the weighted mean seasonal depth and total quantity of precipitation were estimated. In order to determine seasonal depth and quantity of precipitation during the base period, the estimates for the mean period were adjusted on the basis of recorded precipitation at key stations within or near each of the basins. The results of these estimates are listed in the following tabulation:

	:	Estimated	:	Estimated
	:	mean seasonal	:	average seasonal
Ground water	:	precipitation,	:	precipitation during
basin	:	in acre-feet	:	base period
	:		:	in acre-feet
Firu		9,400		9,600
Fillmore		26,300		25,800
Santa Paula		18,800		18,500
Oxnard Forebay		8,700		8,400
Simi		12,400		13,300

### Runoff

The watersheds within and tributary to Ventura County vary markedly in their production of runoff, depending on their areal extent and other physical characteristics, and on the depth of precipitation. Unit runoff is the greatest from the watersheds of the Ventura River, Santa Paula Creek, and Sespe Creek, with lower values from the watersheds of Piru Creek and Santa Clara River above the Ventura County line. Runoff from the Calleguas Creek system is of relatively minor magnitude. Tributary runoff is disposed of through percolation to ground water storage in absorptive stream channels and artificial spreading grounds, evapora-

tion, consumptive use of native vegetation, diversions to meet requirements of irrigated agriculture and urban entities, and discharge to the ocean.

#### Stream Gaging Stations and Records

Long-term records of runoff from streams within or tributary to Ventura County are not available. The longest unbroken records of stream flow in the County are for Matilija Creek at Matilija and Santa Paula Creek near Santa Paula, which are continuous from 1927 to the present time. Broken records extending back to 1911 are available for Ventura River near Ventura, Piru Creek near Piru, and for Sespe Creek, where stations have been maintained at three locations. Continuous records of runoff during the base period are available for Matilija Creek at Matilija, North Fork of Matilija Creek at Matilija, Coyote Creek near Ventura, Ventura River near Ventura, Santa Clara River near Saugus, Piru Creek near Piru, Sespe Creek near Fillmore, Santa Paula Creek near Santa Paula, Arroyo Simi near Simi, and Arroyo Las Posas near Moorpark. In general, records of runoff from minor streams throughout the County are nonexistent, except for those instances where such records were obtained during the present investigation and the investigation for Division of Water Resources Bulletin No. 46.

Locations of stream gaging stations pertinent to the evaluation of the water supply of Ventura County, including the five established in connection with the Ventura County Investigation, are shown on Plate 7 entitled "Stream Gaging and Water Sampling Stations". In general, map reference numbers shown on Plate 7 are those presented in State Water Resources Board Bulletin No. 1, "Water Resources of

California". However, for stations not reported in Bulletin No. 1, arbitrary numbers have been assigned, prefixed by an appropriate County designation; i.e., V.C., Ventura County or L.A., Los Angeles County. Table 5 presents a list of the stations shown on Plate 7, together with map reference numbers, drainage areas, periods and sources of records. Records for the five stations established and maintained by the Division of Water Resources during the investigational seasons, and for San Antonio Creek near Mouth, Santa Clara River near Montalvo, Arroyo Simi near Simi, and Arroyo Las Posas near Moorpark, established and maintained by the Ventura County Water Survey, are available in the files of the Division of Water Resources. The Los Angeles County Flood Control District publishes the records for Santa Clara River  $\frac{1}{2}$  mile west of County line, Santa Clara River above Lang Railroad Station, Placerita Creek at Ridge Route Highway, and Castaic Creek at State Highway 126. The United States Geological Survey publishes the records for all remaining stations listed in Table 5.



TABLE 5

## STREAM GAGING STATIONS IN OR NEAR VENTURA COUNTY

Map reference: number :	Stream	Station	Drainage: area, in: square : miles :	Period: of : record:	Source of record
4- 1	Matilija Creek	At Matilija	55	1927-53	USGS
4- 2	North Fork Matilija Creek	At Matilija	15.5	1928-32 1933-53	USGS
4- 3	Coyote Creek	Near Ventura	41	1927-32 1933-53	USGS
4- 4	Ventura River	Near Ventura	187	1911-14 1929-53	USGS
4- 5	Santa Clara River	Near Saugus	410	1929-53	USGS
4- 6	Piru Creek	Near Piru	432	1911-13 1927-53	USGS
4- 7	Hopper Creek	Near Piru	23	1930-32 1933-36 1937-53	USGS
4- 8	Sespe Creek	At Brad- field's Camp	208	1915-27	USGS
4- 9	Sespe Creek	At Sespe	257	1911-13 1927-34	USGS
4-10	Sespe Creek	Near Fillmore	254	1934-53	USGS
4-11	Santa Paula Creek	Near Santa Paula	40	1912-13 1927-53	USGS
4-12	Santa Clara River	Near Montalvo	1,596	1927-32 1947-53	VCWS
4-14	Malibu Creek	At Crater Camp, near Calabasas	103	1931-53	USGS
VC- 1	Matilija Creek	Above Matilija Reservoir	51	1948-53	USGS
VC- 2	San Antonio Creek	Near Mouth	51	1949-53	VCWS
VC- 3	San Antonio Creek	Near Ojai	34	1927-32 1951-52	DWR

TABLE 5 (Continued)

## STREAM GAGING STATIONS IN OR NEAR VENTURA COUNTY

Map reference: number	Stream	Station	Drainage: area, in: square miles	Period: of record:	Source of record
VC- 4	Santa Clara River	$\frac{1}{2}$ mile west of County line	644	1948-53	LACFCD
VC- 5	Sespe Creek	Near Wheeler Springs	50	1948-53	USGS
VC- 6	Tapo Creek	Near Santa Susana	17	1951-53	DWR
VC- 7	Arroyo Simi	Near Simi	75	1933-53	VCWS
VC- 8	Arroyo Las Posas	Near Moorpark	118	1933-52	VCWS
VC- 9	Calleguas Creek	Near Camarillo	169	1928-31 1951-53	DWR
VC-10	Conejo Creek	Near Camarillo	70	1927-31 1951-53	DWR
VC-11	Calleguas Creek	At Camarillo State Hospital	251	1951-53	DWR
LA- 1	Santa Clara River	Above Lang Rail- road Station	157	1949-53	LACFCD
LA- 2	Placerita Creek	At Ridge Route Highway	41	1947-53	LACFCD
LA- 3	Castaic Creek	At State High- way 126	203	1945-53	LACFCD

USGS  
VCWS  
LACFCD  
DWR

United States Geological Survey  
Ventura County Water Survey  
Los Angeles County Flood Control District  
Division of Water Resources

## Runoff Characteristics

Runoff from streams in Ventura County is derived primarily from rainfall, and as a result exhibits similar monthly and seasonal variations. Absence of snowpack in tributary watersheds causes all streams to diminish rapidly in flow at the conclusion of the winter precipitation season, although some summer flow is maintained by springs in the upper reaches of the more productive watersheds. Following a severe storm, discharge in the larger streams has been known to increase in a few hours time from practically no flow to a rate of thousands of cubic feet per second. Seasonal natural runoff in the principal streams of the County has varied from a maximum in excess of 400 per cent of the mean to a minimum of less than five per cent of the mean. Seasonal vagaries in the runoff of Ventura County streams are represented graphically on Plate 8, entitled "Estimated Seasonal Natural Runoff of Sespe Creek Near Fillmore". The apparent cyclic nature of the occurrence of runoff at this station is shown on Plate 9, entitled "Accumulated Departure from Mean Seasonal Natural Runoff of Sespe Creek near Fillmore". The monthly variation in seasonal runoff is shown in Table 6.

TABLE 6

ESTIMATED AVERAGE MONTHLY DISTRIBUTION  
OF NATURAL RUNOFF OF  
SESPE CREEK NEAR FILLMORE,  
1936-37 THROUGH 1950-51

Month	Runoff, in acre-feet	Per cent of seasonal total
October	790	0.8
November	1,830	1.9
December	7,120	7.5
January	9,480	10.0
February	24,510	25.9
March	32,280	34.1
April	10,930	11.5
May	3,760	4.0
June	1,820	1.9
July	960	1.0
August	640	0.7
September	700	0.7
TOTALS	94,800	100.0

#### Quantity of Runoff

As described previously, long-term records of runoff in Ventura County streams are not available. The natural runoff for each season of the mean period was estimated in State Water Resources Board Bulletin No. 1 for Ventura River near Ventura, Piru Creek near Piru, Sespe Creek near Sespe, Santa Paula Creek near Santa Paula, Santa Clara River at County Line, and Malibu Creek at Crater Camp near Calabasas. Table 7 presents the natural runoff of three representative streams in the County for each season of the base period, together with the seasonal "runoff index" for each of the streams. The term "runoff index" refers to the ratio of the amount of runoff during a given season or period to the mean seasonal amount, and is expressed as a percentage.



TABLE 7

ESTIMATED SEASONAL NATURAL RUNOFF OF SELECTED STREAMS  
OF VENTURA COUNTY, 1936-37 THROUGH 1950-51

Season	Matilija Creek		Piru Creek		Sespe Creek	
	at Matilija		near Piru		near Sespe	
	: Runoff,		: Runoff,		: Runoff,	
	: Runoff : in		: Runoff : in		: Runoff: in	
	: index	: acre-feet	: index	: acre-feet	: index	: acre-feet
1936-37	182	51,200	130	69,700	182	171,000
1937-38	288	81,200	240	129,000	255	239,000
1938-39	47	13,200	71	38,200	49	46,200
1939-40	31	8,700	36	19,400	35	32,500
1940-41	444	125,300	421	226,000	400	376,000
1941-42	46	13,000	60	32,200	45	42,200
1942-43	212	59,700	190	102,000	182	171,000
1943-44	133	37,600	233	125,000	152	143,000
1944-45	51	14,400	64	34,400	58	54,400
1945-46	64	18,100	60	32,300	69	64,400
1946-47	34	9,500	53	28,400	48	45,300
1947-48	9	2,400	12	6,600	9	8,100
1948-49	9	2,600	11	6,000	10	9,100
1949-50	13	3,600	14	7,300	18	16,900
1950-51	5	1,300	4	2,400	4	3,500
Average for 15- year base period, 1936-37 through 1950-51	105	29,500	107	57,300	101	94,800
Average for wet period, 1936-37 through 1943-44	173	48,700	173	92,700	163	152,600
Average for drought period, 1944-45 through 1950-51	26	7,400	31	16,800	31	28,800
Mean for 53-year period, 1894-95 through 1946-47	100	28,200	100	53,700	100	93,900

The actual quantity of surface runoff during the base period was evaluated from records at thirteen key stream gaging stations. Where records were not continuous over the base period, estimates for the missing seasons were made by correlation with nearby stations. Unmeasured runoff was estimated by correlation with runoff at a key station or from rainfall-runoff relationships. Table 8 presents measured and estimated seasonal runoff for the base period at the thirteen key stations.

TABLE 8

MEASURED AND ESTIMATED SEASONAL RUNOFF AT KEY STREAM GAGING STATIONS  
IN OR NEAR VENTURA COUNTY  
1936-37 THROUGH 1950-51

(In acre-feet)

Season	Station and map reference number									
	: : Matilija Creek: : at Matilija, : : 4-1 :	: : North Fork : : Matilija Creek: : at Matilija, : : 4-2 :	: : Coyote Creek : : near Ventura, : : 4-3 :	: : Ventura River : : near Ventura, : : 4-4 :	: : Arroyo Simi : : near Simi, : : VC-7 :	: : Arroyo Las : : Posas near:at, : : VC-8 : : Malibu Creek : : near Calababas, : : 4-14 :				
1936-37	51,230	13,590	22,280	108,100	546	1,010	23,940			
1937-38	81,160	22,920	26,560	190,100	1,580	4,130	34,100			
1938-39	13,200	2,740	3,000	18,960	31	24	4,630			
1939-40	8,660	2,250	2,430	10,940	7	8	6,100			
1940-41	125,280	31,290	50,890	256,300	7,150	9,350	73,220			
1941-42	12,950	4,300	3,630	22,210	0	0	1,820			
1942-43	59,660	15,970	28,910	136,500	2,950	3,080	47,600			
1943-44	37,620	9,870	15,190	74,770	4,170	4,460	30,170			
1944-45	14,350	4,820	7,270	30,080	36	42	4,240			
1945-46	18,130	5,150	3,600	23,340	54	48	3,800			
1946-47	9,540	3,000	2,830	11,400	277	381	3,820			
1947-48	2,200	760	50	50	0	1	180			
1948-49	2,700	1,150	140	160	0	0	90			
1949-50	3,100	1,630	1,470	2,660	0	0	480			
1950-51	1,540	590	100	0	0	0	60			
Average for base period, 1936-37 through 1950-51	29,420	8,000	11,220	59,040	1,120	1,500	15,620			
Average for wet period, 1936-37 through 1943-44	46,720	12,870	19,110	102,240	2,050	2,760	27,700			
Average for drought period, 1944-45 through 1950-51	7,370	2,440	2,210	9,670	52	67	1,810			

TABLE b (Continued)

MEASURED AND ESTIMATED SEASONAL RUNOFF AT KEY STREAM GAGING STATIONS  
IN OR NEAR VENTURA COUNTY  
1936-37 THROUGH 1950-51

(In acre-feet)

Season	Station and map reference number									
	Santa Clara River :	Santa Clara River : 1/2 mile west	Piru Creek :	Hopper Creek :	Sespe Creek :	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near
	Saugus, : 4-5 :	of County Line : VC-4 :	near Piru, : 4-6 :	near Piru, : 4-7 :	near Fillmore, : 4-10 :	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near	Santa Paula Creek near
1936-37	4,850	20,420	69,670	7,700	165,800	31,910	31,910	31,910	31,910	31,910
1937-38	26,900	56,290	128,700	14,770	232,300	44,320	44,320	44,320	44,320	44,320
1938-39	10,180	26,800	38,210	1,450	39,890	8,460	8,460	8,460	8,460	8,460
1939-40	1,570	14,010	19,420	800	27,920	5,300	5,300	5,300	5,300	5,300
1940-41	41,320	79,900	226,300	15,400	371,700	57,680	57,680	57,680	57,680	57,680
1941-42	23,400	43,670	32,190	1,340	37,230	6,890	6,890	6,890	6,890	6,890
1942-43	47,170	74,110	101,900	12,010	165,500	39,740	39,740	39,740	39,740	39,740
1943-44	49,770	86,110	125,200	5,610	136,700	22,430	22,430	22,430	22,430	22,430
1944-45	11,050	25,360	34,380	1,610	49,370	12,180	12,180	12,180	12,180	12,180
1945-46	6,440	19,880	32,330	2,040	59,480	11,190	11,190	11,190	11,190	11,190
1946-47	11,150	24,580	28,380	1,990	40,730	7,310	7,310	7,310	7,310	7,310
1947-48	2,270	11,980	6,630	260	4,380	1,720	1,720	1,720	1,720	1,720
1948-49	1,300	8,800	6,020	380	6,230	1,960	1,960	1,960	1,960	1,960
1949-50	890	6,710	7,270	1,020	13,920	3,490	3,490	3,490	3,490	3,490
1950-51	220	4,280	2,410	140	1,290	990	990	990	990	990
Average for base period, 1936-37 through 1950-51	15,900	33,530	57,270	4,430	90,160	17,040	17,040	17,040	17,040	17,040
Average for wet period, 1936-37 through 1943-44	25,640	50,160	92,700	7,380	147,130	27,090	27,090	27,090	27,090	27,090
Average for drought period, 1944-45 through 1950-51	4,760	14,510	16,770	1,060	25,060	5,550	5,550	5,550	5,550	5,550



Historically, foreign water has entered the Santa Clara River drainage area through release from the Los Angeles Aqueduct or as a result of spill from the Bouquet Canyon terminal reservoir on the aqueduct. Harold Conkling, Consulting Engineer, in his report entitled "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District, September, 1949", estimated the monthly accretions to the Santa Clara River system from this source for the period from 1925-26 through 1947-48. Estimated amounts for the calendar years 1948 through 1951 were obtained from the United Water Conservation District. These estimates indicate that a total of about 60,900 acre-feet of water from the Los Angeles Aqueduct was discharged into the Santa Clara River during the base period. The amounts varied from zero in several seasons to a maximum of about 20,000 acre-feet in 1938-39. Although this release contributed to the historical water supply of Ventura County, adequate data were not available to determine the quantitative effect thereof. Studies did indicate that in most years a substantial portion of the release percolated in the Santa Clara River channel above the Ventura County line. Furthermore, in certain years when releases were made during periods of flood flow, aqueduct water comingled with local waters and passed through Ventura County to the ocean. Although the percolation of aqueduct water above the County line undoubtedly has affected the rising water at the upper limit of the Piru ground water basin, this influence has been estimated to be of small magnitude and has not been considered in this bulletin.

#### Imported Water

Imported water comprises a relatively minor item in the

water supply of Ventura County. Since 1940, Santa Clara River water has been imported by the Newhall Land and Farming Company from a well field in Los Angeles County near Castaic Junction for use in the Piru ground water basin. About 1,300 acres of land on both sides of the river between the County line and the town of Piru are served by the import. The following tabulation presents the seasonal amount of this import for the period from 1939-40 through 1950-51:

<u>Season</u>	<u>Acre-feet</u>	<u>Season</u>	<u>Acre-feet</u>
1939-40	900	1945-46	2,053
1940-41	1,400	1946-47	2,261
1941-42	1,842	1947-48	2,837
1942-43	1,801	1948-49	3,182
1943-44	1,682	1949-50	3,840
1944-45	1,851	1950-51	3,680

#### Underground Hydrology

Regulation and reregulation of the water supplies of Ventura County is accomplished almost entirely through storage in underlying ground water reservoirs. The ground water supplies are found in the valleys and some hill areas in the southerly portion of the County, occurring principally in alluvium and unconsolidated sediments, and to a lesser extent in consolidated and fractured rocks of sedimentary and volcanic origin. These underground reservoirs are replenished by percolation of surface waters, both in natural channels and in spreading grounds constructed for this purpose, by deep penetration of precipitation and the unconsumed portion of applied irrigation water, and by subsurface inflow from adjacent ground water basins. Disposal of ground water supplies is effected by pumped extractions, by effluent discharge and consumptive use of native vegetation in areas of high ground water, and by subsurface outflow.

In connection with the discussion of underground hydrology in this bulletin, the following terms are used as defined:

Key Well--A well chosen for study because it indicates specified ground water characteristics that are considered representative of a given ground water basin or aquifer, or a portion thereof.

Free Ground Water--This generally refers to a body of ground water not overlain by impervious materials, and moving under control of the water table slope. In areas of free ground water, the ground water basin provides storage to regulate available water supplies. Changes in ground water storage are indicated by changes in ground water levels.

Confined Ground Water--A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and moving under pressure caused by the difference in head between intake and discharge areas of the confined water body.

Specific Yield--This term, when used in connection with ground water, refers to the ratio of the volume of water a saturated material will yield by gravity to its own volume, and is commonly expressed as a percentage. Ground water storage capacity is estimated as the product of the specific yield and the volume of material in the depth intervals considered.

Specific Capacity--The number of gallons per minute produced by a pumping well per foot of drawdown.

Drawdown--The lowering of the water level in a well caused by pumping, measured in feet.

Results of investigation of the 17 major ground water basins which have been identified in Ventura County are discussed in this section. In addition to the 17 major basins, there are several other ground water basins in the County which, because of their



relatively small storage capacity and minor present utilization, have not been given detailed consideration in this bulletin. Plate 11, entitled "Ground Water Basins", shows the location of each of the 17 basins, and of selected key wells employed in analyzing the basin characteristics. The wells are numbered by the system utilized by the United States Geological Survey, according to the township, range, and section subdivision of the Federal land survey. In the portions of Ventura County not so subdivided, the township, range, and section lines have been projected. Under the system, each section is divided into 40-acre plots, which are lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Wells are numbered within each of these 40-acre plots according to the order in which they are located. For example, a well having a number 3N/21W-20M1 would be found in Township 3 North, Range 21 West, and in Section 20. It would be further identified as the first well located in the 40-acre plot lettered M. All well numbers in Ventura County refer to the San Bernardino Base Line and Meridian.

The 17 major ground water basins of Ventura County vary considerably in economic importance, depending on their usable storage capacity, areal extent, seasonal recharge, and the ease with which ground water is yielded to pumping wells. The present studies of underground hydrology included investigation of the geologic characteristics of each of the basins, together with quantitative analysis of replenishment and disposal of ground waters therein.



The geologic investigation included collection and analysis of prior geologic reports and maps, supplemented by discussion with geologists familiar with various portions of the County. Drillers logs for 1,534 water wells and 138 oil wells were collected and analyzed. These data, together with additional information obtained by field surveys, were utilized in preparing Plate 10, entitled "Areal Geology", Plates 12-A, 12-B, and 12-C, entitled "Geologic Sections", and Plate 13, entitled "Diagrammatic Sketch of Oxnard Plain and Oxnard Forebay Basins". The locations of the geologic sections are shown on Plate 11.

Aquifers of significance in ground water pumping were identified from well data, and are shown on the geologic sections. Boundaries of ground water basins were established from geologic evidence, and from analysis of the occurrence and movement of ground water as depicted on the representative ground water contour maps listed in the following tabulation:

<u>Plate Number</u>	<u>Title</u>
14-A, B, C.	Lines of Equal Elevation of Ground Water, Fall of 1936.
15-A, B, C.	Lines of Equal Elevation of Ground Water, Spring of 1944.
16-A, B, C.	Lines of Equal Elevation of Ground Water, Fall of 1951.
17-A, B, C.	Lines of Equal Depth to Ground Water, Fall of 1951.
18-A, B, C.	Lines of Equal Change in Ground Water Elevation, Fall of 1936 to Fall of 1951.
19-A, B, C.	Lines of Equal Change in Ground Water Elevation, Spring of 1944 to Fall of 1951.

Estimates were made of specific yield of the water-bearing formations and of storage capacity of the ground water basins. Methods and procedures utilized in preparing these estimates are described in Appendix B. From these data, and from information on fluctuations of the level of water in wells, changes in ground water storage occurring in ground water basins during selected periods of hydrologic significance were estimated. Plate 20, entitled "Fluctuation of Water Levels at Key Wells", presents hydrographs of ground water elevation at 18 key wells in 14 of the 17 major ground water basins. Plate 21, entitled "Relationship Between Water Levels at Key Wells and Ground Water Storage Depletion", shows graphically the relationship between ground water storage depletion and the elevation of the ground water surface at key wells in Ojai, Piru, Fillmore, Santa Paula, Oxnard Forebay, and Simi Basins. Water level measurements utilized in preparing all plates relating to the occurrence and movement of ground water and fluctuations of ground water levels, were obtained from the Ventura County Water Survey.

The effects of draft on and replenishment of the ground water basins were analyzed for the base period, from 1936-37 through 1950-51, in an attempt to ascertain how and to what extent the basins could be utilized to regulate available water supplies to meet present and probable future water requirements of Ventura County. These studies included analysis of data on precipitation, surface runoff, and records of diversions of surface flow from principal streams in the County. Estimates were made of consumptive use of water and of ground water extractions as described in Chapter III. Recharge of ground water basins from stream channel percolation was estimated from data appear-

ing in Division of Water Resources Bulletin No. 46, modified and supplemented in accordance with more recent information including measurements made during the investigation. Where adequate data were available, subsurface inflow to and outflow from the ground water basins were estimated by means of either the "rising water" or "slope-area" methods, or both, descriptions of which are included in Appendix B.

The ensuing discussion presents pertinent data and the results of studies for each of the 17 major ground water basins. As will be noted, the degree of detail to which these studies were conducted varied among the basins, depending on the relative importance of the basin and the availability of basic hydrologic data.

#### Ventura Hydrologic Unit

Four major ground water basins have been identified in the Ventura Hydrologic Unit. These basins, designated Upper Ojai, Ojai, Upper Ventura River, and Lower Ventura River, comprise a total surface area of about 15,650 acres. The remaining lands of the unit are principally underlain by formations of low permeability which do not yield water readily to wells. Table 9 summarizes certain physical characteristics of the four ground water basins.

TABLE 9

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS  
IN VENTURA HYDROLOGIC UNIT

Basin	Area, in acres	Estimated average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated: depth from: ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Upper Ojai	1,950	8	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-300	0-300	Unconfined	50
Ojai	6,040	5.5	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-700	0-700	Essentially unconfined; locally semi- confined	400
Upper Ventura River	4,990	8	Recent and Pleistocene alluvium	Sand and gravel beds	0-100	0-100	Unconfined	600
Lower Ventura River	2,670	8	Recent and Pleistocene alluvium	Sand and gravel beds	0-100	0-100	Unconfined	---

\* In zone of historic water level change.



Upper Ojai Basin. Upper Ojai Basin, with a surface area of about 1,950 acres, lies in the northeasterly portion of the Ventura Hydrologic Unit, at elevations varying between 1,200 and 1,600 feet above sea level. Surface waters in the basin drain both to the west through Lion Canyon into San Antonio Creek, and to the east via Sisar Creek to Santa Paula Creek.

Water-bearing materials in Upper Ojai Basin consist of Recent and Pleistocene gravels, sands, and clays, and to a lesser extent weathered consolidated sediments of Tertiary age. The average thickness of the water-bearing materials has been estimated to approximate 60 feet, attaining an estimated maximum depth of about 300 feet near Sisar Creek. In general, ground water in the basin is unconfined, with a direction of movement conforming to the surface slope, as shown on Plate 16-A. The basin is replenished by deep penetration of precipitation, by percolation of surface water in minor watercourses, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water effluent appears in springs at both the easterly and westerly extremities of the basin.

Ground water in Upper Ojai Basin is presently utilized to meet relatively minor domestic and irrigation requirements. Wells yield between 10 and 200 gallons per minute, with an estimated average yield of about 50 gallons per minute. No quantitative estimates were made of the storage capacity of the basin, nor of historic change in ground water storage therein. It is considered probable, however, that the basin is presently utilized to about the maximum practicable extent.

Ojai Basin. Ojai Basin, with a surface area of about 6,040 acres, lies in the northerly portion of the Ventura Hydrologic Unit and to the northwest of Upper Ojai Basin, at elevations varying from about 700 to more than 1,200 feet above sea level. Surface waters in the basin drain southwesterly in San Antonio Creek to the Ventura River.

Water-bearing materials in Ojai Basin consist of Recent and Pleistocene alluvium, which is flanked and underlain by consolidated sediments of Tertiary age that yield minor amounts of water. The alluvium is estimated to extend to a depth of at least 700 feet near the center of the basin. Geologic sections E-E' and F-F' on Plate 12-A depict the configuration of the base of the alluvium.

Ground waters throughout the basin are essentially unconfined, although lenses of clay result in localized confinement of portions of the ground water body. During periods of high ground water levels, flowing wells have been reported in the southwesterly portion of the basin. The direction of normal ground water movement is west and south, with convergence toward the point of outflow of San Antonio Creek, as shown on Plates 14-A and 15-A. However, during drought periods the direction of movement in the southwesterly portion is reversed, as shown on Plate 16-A. Wells supplying requirements of the basin are reported to yield from 100 to 600 gallons per minute, with specific capacities varying from 3 to 20.

Sources of replenishment to ground water in Ojai Basin are percolation of surface waters on the alluvial cones at the mouths of Horn and Senor Canyons, in the channel of San Antonio Creek, and other minor watercourses, deep penetration of precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. In addition, in 1952, an estimated 3,270 acre-feet of water were

delivered to Ojai Basin from Matilija Reservoir. This water was largely spread and percolated at grounds constructed by the Ventura County Flood Control District in the north-central portion of the basin, although minor quantities of the import were sold directly to a few users. Ground water disposal from Ojai Basin is effected by pumped extractions to meet beneficial consumptive uses of overlying irrigated and urban lands, by consumptive use of phreatophytes, and by effluent discharge into San Antonio Creek.

Because of its relatively small storage capacity as related to ground water replenishment and disposal, Ojai Basin is quickly recharged during wet periods, and conversely is rapidly depleted during periods of drought. Seasonal and cyclic fluctuations of the ground water surface at key well number 4N/22W-5L1 are shown on Plate 20. Pumping lifts exhibit wide variation from wet to drought periods. In the fall of 1951, some users in the basin were pumping against heads in excess of 300 feet.

Lack of adequate hydrologic data precluded the evaluation of all items comprising water supply and disposal in Ojai Basin. Studies were made of the effects of draft on and replenishment of the ground water body during the drought period. In the spring of 1944, Ojai Basin was essentially full, and effluent discharge was occurring at its westerly extremity. From the spring of 1944 to the fall of 1951, disposal of ground water exceeded recharge, and ground water storage in the basin was substantially dewatered. Estimated ground water storage depletion during the seven-year drought period amounted to about 28,000 acre-feet. Total consumptive use of water on overlying lands, including that of precipitation, was estimated to have been about 71,000 acre-feet. Consumptive use of applied water during this period was estimated to



have been about 28,200 acre-feet. The net retention of direct precipitation on the ground water basin, and of tributary surface inflow during the period was determined as a differential in solution of the equation of hydrologic equilibrium, and was estimated to have been about 43,000 acre-feet. The hydrologic equation states in effect that the sum of the items comprising the water supply of a given hydrologic unit or area must be equal to the sum of the items of water disposal plus or minus the change in ground water storage.

As shown by sections E-E' and F-F' on Plate 12-A, Ojai Basin has a concave configuration, with the depth of alluvium considerably greater in the center than at the peripheral margin. By the fall of 1947, water levels had so lowered that some wells near the margin had gone dry. Because of this historic limitation in its utility, it was estimated that the usable storage capacity of Ojai Basin, under present pattern of pumping, is equal to the computed total decrement in storage from the spring of 1944 to the fall of 1947, or about 10,900 acre-feet. Total storage capacity of the basin was estimated to be in the order of 70,000 acre-feet. The relationship between unwatered ground water storage in Ojai Basin and elevation of the ground water surface at key well number 4N/22W-5L1 is shown on Plate 21.

Upper Ventura River Basin. Upper Ventura River Basin essentially comprises the alluvial filled Ventura River Valley above the diversion weir of the City of Ventura at Foster Park. The basin has a surface area of about 4,990 acres, ranging in elevation from 200 to more than 800 feet above sea level. Surface waters drain south toward Foster Park.

Water-bearing materials in Upper Ventura River Basin consist of deposits of gravels, sands, and clays of Recent and Pleistocene age.



These deposits are flanked and underlain by consolidated sediments of Tertiary age, which form the bottom and sides of the basin. Section E-E' on Plate 12-A shows the general structure and shape of the basin. For study purposes, Upper Ventura River Basin was taken to comprise only the area underlain by alluvium. Geologic examination during the course of the investigation indicated that depth of the alluvium varies from about 60 feet northwest of Meiners Oaks, to about 80 feet at Foster Park. Maximum depths of over 100 feet occur at various points between Meiners Oaks and Foster Park.

Ground water occurs primarily in the alluvial deposits of Upper Ventura River Basin, and is unconfined. However, minor quantities of water are yielded to irrigation and domestic wells drilled into the Tertiary formations. In general, direction of ground water movement conforms with the slope of the Ventura River bed, as shown on Plates 14-A, 15-A, and 16-A. It was estimated that the total storage capacity of the basin is in the order of 10,000 acre-feet. Although it was not possible to evaluate the usable storage capacity of the basin, it is believed to comprise a relatively small portion of the estimated total capacity. The greatest number of wells in the basin are used for domestic and minor irrigation developments. A few large irrigation wells yield an average of about 600 gallons per minute, with specific capacities varying from 10 to 200.

Percolation of flow in the Ventura River channel is the primary source of recharge to Upper Ventura River Basin, with percolation of direct rainfall, of the unconsumed portion of water applied for irrigation and other uses, and of subsurface inflow from the flanking Tertiary formations comprising secondary sources of supply. Since 1948, discharge in Matilija Creek and percolation therefrom has been affected

by operation of Matilija Reservoir. Ground water in the basin is disposed of by pumped extractions to meet beneficial consumptive uses on overlying and adjacent lands, including extractions by the City of Ventura at its well field upstream from the diversion weir at Foster Park, by consumptive use of phreatophytes, and by effluent discharge and subsurface outflow at Foster Park. The subsurface flow at the east end of the diversion weir at Foster Park was estimated to average less than 100 acre-feet per season.

The limited storage capacity of Upper Ventura River Basin provides only short-term retention to surface runoff, and furnishes but little carry-over storage during a period of drought. The relatively steep slope of the basin results in rapid drainage south toward Foster Park. Ground water levels in the basin respond quickly to changes in the rate of surface flow in the Ventura River.

Percolation of water originating in Matilija and North Fork of Matilija Creeks in the Ventura River channel was estimated from percolation diagrams presented in the report entitled "Safe Yield - Matilija Reservoir, May, 1948" by Harold Conkling, Consulting Engineer. Surface flow in these two streams and percolation to ground water from them meet the greater portion of the water requirements of lands overlying and adjacent to Ventura River Basin and the City of Ventura. Examination of water level measurements available from the Ventura County Water Survey, together with analysis of inflow to the basin from Matilija Creek and the North Fork of Matilija Creek, and surface outflow from the basin as measured at the gaging station on Ventura River near Ventura, indicated that during the drought period the basin was substantially full until the spring of 1947, and that percolation to the basin was adequate to satisfy demands of ground water users,

including the pumping requirements of the City of Ventura. At the same time, surface discharge was sufficient to meet requirements of surface-supplied lands upstream from Meiners Oaks, and to meet the remainder of the City's requirements. Subsequent to the spring of 1947, however, use of water from the basin exceeded seasonal recharge, and water levels progressively dropped until the fall of 1951, when the basin was substantially dewatered. Recharge during the wet season of 1951-52 essentially filled the basin.

It has been stated that relatively high rates of surface flow prevailed in Ventura River Basin in most months during the wet period and during the portion of the drought period from 1944-45 to the spring of 1947. Also, requirements for water by overlying and adjacent users of ground water supplies, and by riparian surface diverters including the City of Ventura, were satisfied during this time of ample surface flow. For these reasons, no attempt was made to quantitatively evaluate recharge to and disposal of ground water supplies in Upper Ventura River Basin prior to the spring of 1947.

From the spring of 1947 through the season of 1950-51, the average seasonal percolation in Upper Ventura River Basin was estimated to have been about 3,100 acre-feet. Present use of water by overlying and riparian users, including the City of Ventura, was estimated to be about 7,700 acre-feet per season. During a wet period, such as that which occurred from 1936-37 through 1943-44, it was estimated that requirements of these users would be satisfied. During a drought period, such as from 1944-45 through 1950-51, it was estimated that, without impairment by operation of Matilija Reservoir, about 4,900 acre-feet of water per season on the average would be available to the users. Under these circumstances, about 3,300 acre-feet per season would have been



available during the period from the spring of 1947 through the season 1950-51. This estimate does not include usable supplies available in ground storage in Upper Ventura River Basin at the beginning of the period, which, as stated previously, were estimated to be of small magnitude.

The estimated seasonal runoff of the Ventura River at the gaging station, Ventura River near Ventura, that would have occurred during the base period with the present pattern of land use and prevailing water requirements, and with Matilija Reservoir in operation, is shown in Table 10.



TABLE 10

ESTIMATED SEASONAL RUNOFF OF VENTURA RIVER  
NEAR VENTURA DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE  
AND WITH MATILIJIA RESERVOIR IN OPERATION

Season	:	Acre-feet
1936-37		97,900
1937-38		186,600
1938-39		17,300
1939-40		8,900
1940-41		253,300
1941-42		19,100
1942-43		134,000
1943-44		72,500
1944-45		28,200
1945-46		21,600
1946-47		9,800
1947-48		0
1948-49		0
1949-50		2,400
1950-51		0
Average for base period, 1936-37 through 1950-51		56,800
Average for wet period, 1936-37 through 1943-44		98,700
Average for drought period, 1944-45 through 1950-51		8,800

Lower Ventura River Basin. Lower Ventura River Basin essentially comprises gravels, sands, and clays of Recent and Pleistocene alluvium in the Ventura River bottom lands between Foster Park and the ocean. The basin has a surface area of about 2,670 acres, varying in elevation from 200 feet above sea level to sea level. Surface waters drain south in the Ventura River channel to the ocean.

Depth of the alluvium in Lower Ventura River Basin varies from about 80 feet at Foster Park to in excess of 100 feet near the mouth of the Ventura River. The alluvium is flanked and underlain by consolidated sediments, most of which are of Tertiary age. Under natural conditions, this basin was undifferentiated from the Upper Ventura River Basin, but it has been treated separately herein because of the impedance to ground water movement effected by the artificial subsurface barrier at Foster Park.

Near the mouth of the river, the alluvium of Lower Ventura River Basin is underlain by water-bearing deposits of the San Pedro formation. It is believed that there is little if any hydraulic connection between the two formations. It is indicated that the San Pedro formation is recharged by percolation of tributary runoff and direct precipitation on its outcrop area in the hills northeasterly of the City of Ventura. The San Pedro formation is considered to be contained within Mound Basin, most of which is included within the Santa Clara River Hydrologic Unit. Thus, near the mouth of the Ventura River, Lower Ventura River Basin overlaps Mound Basin, with free hydraulic connection between the two severed by impermeable clays which confine the ground water in the latter basin.

Ground water in Lower Ventura River Basin is of such inferior mineral quality that the basin is not presently utilized. Lands requiring water service overlying the basin are either served by the City of Ventura or pump ground water from the underlying San Pedro formation. At the present time, an estimated 600 acre-feet of water per season are so extracted on the average. Of this amount, about 100 acre-feet per season are exported for domestic and industrial use in the Rincon Subunit, northwest of the Ventura River.

## Santa Clara River Hydrologic Unit

From the economic standpoint, the seven major ground water basins identified in the Santa Clara River Hydrologic Unit are the most important in Ventura County. These basins, designated Piru, Fillmore, Santa Paula, Oxnard Forebay, Mound, Oxnard Plain, and Pleasant Valley, comprise a total surface area of about 125,700 acres, varying in elevation from sea level at the mouth of the Santa Clara River to about 800 feet above sea level in the river channel at the easterly county line. Utilization of water extracted from ground water storage in the Santa Clara River Hydrologic Unit meets over 90 per cent of the requirement of an estimated present net irrigated area of about 83,000 acres, as well as the entire requirement of the communities of Oxnard, Port Hueneme, Fillmore, Piru, Saticoy, and other smaller urbanized areas. A small portion of Eastern Basin, a large ground water basin which lies primarily in Los Angeles County, is included within Ventura County immediately east of Piru Basin. However, because of the relatively small areal extent of Eastern Basin within Ventura County, detailed analysis and discussion thereof has not been included in this bulletin.

The Piru, Fillmore, Santa Paula, and Mound Basins overlie the Santa Clara River syncline, which is a deformation in the San Pedro and older formations, and is of considerable significance to the hydrology of the basins. Ground water occurring in the Piru, Fillmore, Santa Paula, and Oxnard Forebay Basins is unconfined, whereas that occurring in the pumped aquifers of the Mound, Oxnard Plain, and Pleasant Valley Basins is under pressure caused by confining clay beds of low permeability. The unconfined ground water basins are replenished by



percolation of flow in the Santa Clara River and its tributaries, percolation of direct precipitation, artificial spreading and percolation of surface waters, and by percolation of the unconsumed residuum of water applied for irrigation and other uses. The pumped pressure aquifers in the Mound, Oxnard Plain, and Pleasant Valley Basins are largely supplied by subsurface flow from areas of free ground water. Ground water in the seven major basins of the Santa Clara River Hydrologic Unit is disposed of by effluent discharge to lower basins, by pumped extractions to meet beneficial consumptive uses, by consumptive use of phreatophytes in areas of high ground water, and by subsurface flow to lower basins and to the ocean.

The effects of draft on and replenishment of ground water basins in the Santa Clara River Hydrologic Unit were analyzed as they would be with the present pattern of land use and under conditions of water supply and climate that occurred during the base period. The general method of analysis employed in these studies involved evaluation of the several items of water supply and disposal, and solution of the equation of hydrologic equilibrium to determine changes in ground water storage. Estimates of tributary surface inflow were made by correlation with measured flow at key gaging stations, records for which were presented earlier in this chapter. Estimates of the quantity of precipitation falling on absorptive areas have also been presented in this chapter. The nature and extent of land use within and adjacent to each of the basins were determined from the results of land use surveys conducted during 1949-50. Consumptive use of water and estimates of ground water extractions were determined as described in Chapter III. Records of surface diversion to irrigated and urban lands were obtained from various sources, and employed as required in the analyses. Stream



channel percolation was estimated from diagrams presented in Division of Water Resources Bulletin No. 46, as modified by the United Water Conservation District in light of more recent percolation measurements. Additional percolation measurements made during the investigation confirmed the validity of the modified diagrams. Subsurface inflow to and outflow from each of the unconfined ground water basins were estimated by the rising water method, and the reasonableness of the results was checked by use of the slope-area method. Both methods are described in detail in Appendix B. Inflow from and outflow to the ocean along the coastal front of Oxnard Plain Basin were estimated from parameters established from records of piezometric levels, and from estimates of ground water extractions.

Table 11 summarizes certain physical characteristics of the seven major ground water basins in the Santa Clara River Hydrologic Unit.

TABLE 11

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS  
IN SANTA CLARA RIVER HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent:	Water-bearing formations	Principal aquifers	Estimated: depth from: ground surface: to base of: aquifers, in feet:	Estimated thickness of aquifers, in feet:	Condition of: occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Piru	6,520	16.7	Recent and Pleistocene alluvium	Sand and gravel beds	0-200	0-200	Unconfined	800
			San Pedro		1,000+	800+	Unconfined	800
Fillmore	16,870	12.2	Recent and Pleistocene alluvium	Sand and gravel beds	0-250	0-250	Unconfined	700
			San Pedro		1,000+	750+	Unconfined	700
Santa Paula	13,520	10.0	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-200	0-200	Essentially unconfined	700
			San Pedro		1,000+	800+	Essentially unconfined	700
Mound	12,300	---	San Pedro	Lenses of permeable sediments near top	1,500+	1,000+	Confined	700

TABLE 11 (Continued)

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS  
IN SANTA CLARA RIVER HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated:		Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
					depth from: ground	thickness of aquifers, in feet		
Oxnard Forebay	6,170	16.5	Recent and Pleistocene alluvium	Most of formation	100-250	100-250	Unconfined	1,100
Oxnard Plain	46,460	---	Recent alluvium	Semi-perched water- bearing zone	0-50	0-50	Unconfined	---
			Upper Pleistocene alluvium	Oxnard aquifer	180-250	75-200	Confined	900
			San Pedro	Fox Canyon	600-1,900	100-300	Confined	900
Pleasant Valley	23,850	---	Recent and Pleistocene alluvium	Permeable lenses not connected with Oxnard aquifer	0-400	---	Essentially confined	400
			San Pedro	Fox Canyon	400-1,500	100-300	Confined	1,000

\* In zone of historic water level change.

Piru Basin. Piru Basin is the uppermost and most easterly of the four unconfined ground water basins in the Santa Clara River Hydrologic Unit. The surface area is about 6,520 acres, and surface elevations in the Santa Clara River channel range from about 800 feet above sea level at the eastern extremity of the basin to about 470 feet at the western extremity. Surface waters drain westerly in the river channel and southwesterly in Piru Creek, a principal tributary.

Water-bearing formations in Piru Basin include Recent and Upper Pleistocene alluvium, underlain by the older San Pedro formation. The alluvium attains depths of 85 to 200 feet. From analyses of oil well logs, the San Pedro formation is estimated to extend to depths as great as 4,000 feet, although the maximum depth of the aquifers presently utilized is about 1,000 feet. As shown on geologic section J-J' on Plate 12-A, the San Pedro formation does not outcrop in Piru Basin. Also shown on section J-J' are the San Cayetano and Oak Ridge faults, which separate the San Pedro formation from flanking nonwater-bearing Tertiary formations.

Ground waters found in Piru Basin are unconfined. As shown on Plates 14-B, 15-B, and 16-B, ground water generally moves to the west in the direction of the surface slope. The water table slope flattens toward the westerly extremity of the basin, where the cross sectional area of the San Pedro formation is reduced by warping of the Santa Clara River syncline. Historically, this constriction has resulted in effluent discharge from the ground water body. The westerly boundary of Piru Basin was arbitrarily drawn at the estimated section of maximum rising water, but could have been drawn equally as well a short distance to the east or west of the assumed line. Most wells in the basin have been drilled to the San Pedro formation, and yield from 600 to 2,000



gallons per minute, with an estimated average yield of about 800 gallons per minute. Specific capacity of wells averages about 70. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 17 per cent.

Ground water storage in Piru Basin is replenished by natural percolation of Piru Creek, Hopper Creek, and Santa Clara River water, and by spreading and percolation of Piru Creek water at grounds constructed by the Santa Clara Water Conservation District near the town of Piru, which are now operated by the United Water Conservation District. Percolation of direct precipitation, and of the unconsumed portion of water applied for irrigation and other uses, including water imported from Eastern Basin, also replenishes the ground water of Piru Basin. Ground water is disposed of by pumped extractions to meet beneficial consumptive uses on overlying and adjacent lands, by exportation to Fillmore Basin, by consumptive use of phreatophytes, by effluent discharge, and by subsurface outflow.

Records of measurements of ground water levels in Piru Basin are available since the late 1920's. Seasonal and cyclic fluctuations of the ground water surface at key well number 4N/19W-25L4 are shown on Plate 20. As depicted by this hydrograph, ground water levels in the basin respond rapidly in accordance with the relative wetness of a given season. The ground water surface at this well had a recorded maximum elevation of about 572 feet in the spring of 1944, and a minimum elevation of about 448 feet in the fall of 1951. Substantial recharge to the ground water body during the wet season of 1951-52 resulted in a sharp rise in the ground water surface at this well, to an elevation of about 536 feet. Ground water storage depletion in Piru Basin at the

beginning of the base period, in the fall of 1936, was estimated to have been about 51,000 acre-feet, while estimated storage depletion in the fall of 1951 was about 94,300 acre-feet. It was further estimated that the basin was essentially full in the spring of 1945. The relationship between elevation of the ground water surface at well number 4N/19W-25L4 and ground water storage depletion in Piru Basin is shown on Plate 21.

By the summer of 1936, following a dry period, nearly all wells pumping from the alluvium on the south side of Piru Basin had gone dry. As a result, overlying users drilled wells nearer the river and into the San Pedro formation, where adequate water supplies were obtained. From examination of geologic section J-J' on Plate 12-A, it appears that these overlying users could have drilled much deeper wells at the original sites and intercepted the water-bearing San Pedro formation. For these reasons, it is believed that the utility of Piru Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

Analysis was made of water supply and disposal in Piru Basin during the base period to determine changes in ground water storage, assuming that the present pattern of land use prevailed over this period. Although the method of analysis generally described earlier in this chapter was utilized, the evaluations of certain of the items of water supply and disposal warrant further description. Unmeasured flood flow in the Santa Clara River from Los Angeles County was estimated by correlation with recorded flow at the gaging station on the Santa Clara River near Saugus, maintained by the Los Angeles County Flood Control District. Effluent discharge from Eastern Basin to Piru Basin was

estimated from data appearing in the report entitled "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District, September 1949", by Harold Conkling, Consulting Engineer, and in biennial reports on hydrologic data prepared by the Los Angeles County Flood Control District. Minor tributary surface inflow was estimated by correlation with recorded flow of Hopper Creek. Percolation of surface inflow to the ground water basin was estimated from records of diversion to the spreading grounds near Piru, and from percolation diagrams indicating losses in Piru and Hopper Creeks and the Santa Clara River channel, for various rates of discharge. Exports from the basin were taken from the records of the Sespe Land and Water Company, Southside Improvement Company, and the State Fish Hatchery. As the latter entity did not export water prior to 1948, the probable exportation that would have been made over the base period was estimated by extending the exports of record. Effluent discharge from the basin was estimated from the determined correlation between measured rates of discharge and slopes of the ground water surface. Flood flow leaving the basin was taken as the difference between total surface inflow and percolation in the stream channels and in the spreading grounds near Piru.

The hydrologic studies were conducted on a monthly basis over the base period, commencing with an assumed basin storage depletion in the fall of 1936 of 94,300 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study, the basin would have first filled in February, 1938, and would have remained essentially full, with the exception of the seasons of 1938-39 and 1939-40, until the spring of 1945. From that time until the fall of 1951, disposal of water in the basin would have exceeded

recharge, and basin storage would have again been depleted in the amount of 94,300 acre-feet by the fall of 1951. Since this storage depletion is equal to that which actually prevailed in the fall of 1951, it is indicated that subsequent to the last filling of the basin in the spring of 1945, conditions assumed for the study were equivalent to actual historical conditions.

A seasonal summary of the foregoing hydrologic analysis of Piru Basin is presented in Table 12.



TABLE 12

ESTIMATED SEASONAL STORAGE DEPLETION IN PIRU BASIN DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

SEASON	ITEMS OF WATER SUPPLY					ITEMS OF WATER DISPOSAL					CHANGE		
	SURFACE	IMPORT	PRECIPITATION	SUBTOTAL	OUTFLOW	SURFACE	SUBSURFACE	EXPORT	APPLIED	CONSUMPTIVE USE	IN	GROUND	STORAGE
	INFLOW					OUTFLOW			WATER	OF	WATER	WATER	DEPLETION AT
									ON BASIN*		STORAGE	STORAGE	END OF SEASON
1935-36	109,500	0	13,800	123,300	40,900	17,600	5,400	5,400	6,600	8,200	14,800	78,700	94,300
1936-37	222,200	0	13,000	235,200	157,700	21,600	5,400	5,400	7,300	7,300	14,600	199,300	49,700
1937-38	68,700	0	8,300	77,000	40,400	21,600	5,700	5,700	6,800	7,300	14,100	81,800	13,800
1938-39	35,500	900	8,000	44,400	18,200	21,600	5,700	5,700	7,100	7,100	14,200	59,700	18,600
1939-40	345,100	1,400	20,200	366,700	299,000	21,600	5,200	5,200	6,100	8,900	15,000	340,800	33,900
1940-41	79,200	1,800	6,900	87,900	57,200	21,600	5,800	5,800	6,500	7,200	13,700	98,300	8,000
1941-42	206,400	1,800	15,600	223,800	178,900	21,600	6,000	6,000	7,200	7,500	14,700	221,200	18,400
1942-43	225,400	1,700	13,600	240,700	192,600	21,600	5,900	5,900	7,400	7,300	14,700	234,800	15,800
1943-44	63,800	1,900	8,200	73,900	38,700	21,600	5,900	5,900	7,400	7,200	14,600	80,800	9,900
1944-45	57,400	2,000	7,900	67,300	32,300	21,600	6,100	6,100	7,300	6,900	14,200	74,200	16,800
1945-46	58,100	2,300	7,900	68,300	29,700	21,600	6,200	6,200	8,400	6,400	14,800	72,300	23,700
1946-47	19,300	2,800	4,300	26,400	5,000	21,600	6,000	6,000	7,800	5,600	12,400	46,000	27,700
1947-48	15,700	3,200	4,500	23,400	1,100	21,300	5,600	5,600	7,500	5,800	13,300	41,300	47,300
1948-49	16,600	3,800	6,500	26,900	1,500	18,000	4,900	4,900	7,400	7,000	14,400	38,800	65,200
1949-50	7,100	3,700	4,400	15,200	300	13,800	5,000	5,000	7,600	5,700	13,300	32,400	77,100
1950-51													94,300
AVERAGE FOR BASE PERIOD, 1936-37 THROUGH 1950-51	102,000	1,800	9,600	113,400	72,900	20,600	5,700	5,700	7,200	7,000	14,200	113,400	
AVERAGE FOR WET PERIOD, 1936-37 THROUGH 1943-44	161,500	1,000	12,400	174,900	123,100	21,100	5,600	5,600	6,900	7,600	14,500	164,300	
AVERAGE FOR DROUGHT PERIOD, 1944-45 THROUGH 1950-51	34,000	2,800	6,200	43,000	15,500	19,900	5,700	5,700	7,600	6,400	14,000	55,100	

\* INCLUDES TOTAL CONSUMPTIVE USE OF PHREATOPHYTES.

Fillmore Basin. Fillmore Basin is situated westerly of and downstream from Piru Basin. The surface area is about 16,870 acres, and surface elevations in the Santa Clara River channel vary from about 470 feet above sea level at the easterly extremity of the basin to about 280 feet at its westerly limit near the City of Santa Paula. Surface waters drain westerly in the river channel, and southwesterly in Sespe Creek, a principal tributary.

Water-bearing formations in Fillmore Basin include Recent and Pleistocene alluvium having a maximum depth of about 250 feet, underlain by the older San Pedro formation, which extends to depths as great as 4,000 feet. As in Piru Basin, aquifers of the San Pedro formation are presently utilized to a maximum depth of about 1,000 feet. The Oak Ridge fault defines the southerly limit of the San Pedro formation, as shown on geologic section H-H' on Plate 12-A. With the exception of an outcrop area of about 1,600 acres near the westerly limit of Fillmore Basin, the San Pedro formation is entirely overlain by the alluvium.

Ground waters found in Fillmore Basin are unconfined except in certain relatively minor local areas. Ground water moves generally in a westerly direction in conformity with the slope of the ground surface. At the westerly boundary of the basin, the cross sectional area of the San Pedro formation is reduced by local warping of the Santa Clara River syncline. Upstream from the boundary, there is a flattening in the slope of the ground water surface and effluent discharge of ground water prevails most of the time. Near the constriction, there is a steepening of the slope of the ground water surface. Downstream from the constriction, the cross sectional area of the San Pedro formation is greater, with an accompanying decrease in the slope of the ground water surface. The westerly boundary of the Fillmore Basin was

arbitrarily drawn at the section of estimated maximum rising water. Irrigation wells in Fillmore Basin yield up to 2,100 gallons per minute, with an estimated average yield of about 700 gallons per minute. Specific capacity of wells varies considerably, but probably averages on the order of 50. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 12 per cent.

Ground water storage in Fillmore Basin is replenished by percolation of surface flow in the Santa Clara River, Sespe Creek, and minor tributary streams, subsurface inflow from Piru Basin, deep penetration of direct precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. Some contribution of minor magnitude may occur through lateral underflow of water from adjacent semi-permeable formations. Ground water in the basin is disposed of by pumped extractions to meet requirements of overlying and adjacent lands, by consumptive use of phreatophytes, and by effluent seepage and subsurface outflow into Santa Paula Basin.

During periods of drought, water levels in the central portion of Fillmore Basin exhibit a greater differential lowering than in the westerly portion where rising water usually prevails. During the recent drought period, alluvium in the central portion of the basin on both the north and south sides of the Santa Clara River was substantially dewatered. On the north side of the river, most wells drawing from the alluvium also penetrate the San Pedro formation, and yields therefrom were not seriously affected by this dewatering. However, some domestic wells drawing from the alluvium south of the Oak Ridge fault were dry during the latter years of the drought. Static depth



to ground water in the fall of 1951 at key well number 4N/20W-36N2 averaged about 60 feet. The hydrograph for this well is shown on Plate 20. At this time storage depletion in the basin was an estimated 61,000 acre-feet, which was the greatest of record. The relationship between elevations of the ground water surface at well number 4N/20W-36N2 and ground water storage depletion in Fillmore Basin is shown on Plate 21. Based on available data, and for reasons similar to those cited in the case of Piru Basin, it is believed that utility of Fillmore Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

The seasonal results of the monthly hydrologic analysis of Fillmore Basin are summarized in Table 13. In this study, the items of surface inflow from Piru Basin were taken from the corresponding items of outflow in the analysis for Piru Basin presented in Table 12. Additional surface inflow to Fillmore Basin comprised measured runoff of Sespe Creek, together with measured diversions from Sespe Creek by the Fillmore Irrigation Company. Minor tributary runoff was estimated by correlation with measured flows of Hopper Creek. Import to Fillmore Basin was taken as equal to the export from Piru Basin by the State Fish Hatchery, Sespe Land and Water Company, and Southside Improvement Company. Surface outflow other than rising water was taken as the difference between total surface inflow less percolation in the basin.

The hydrologic study commenced with an assumed basin storage depletion in the fall of 1936 of 61,000 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study the basin would have first filled in the spring of 1937, and would have filled each spring thereafter through 1947.



From that time until the fall of 1951, disposal of water in the basin would have exceeded recharge, and basin storage would have again been depleted in the amount of 61,000 acre-feet by the fall of 1951. Since this storage depletion is equal to that which actually prevailed in the fall of 1951, it is indicated that subsequent to the last filling of the basin in the spring of 1947, conditions assumed for the study were equivalent to actual historic conditions.

TABLE 13

ESTIMATED SEASONAL STORAGE DEPLETION IN FILLMORE BASIN DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

SEASON	ITEMS OF WATER SUPPLY						ITEMS OF WATER DISPOSAL						CHANGE IN STORAGE	SUBTOTAL: GROUND DEPLETION AT END OF SEASON																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	SURFACE			PRECIPITATION			SUBSURFACE			EXPORT					PRECIPITATION	SUBTOTAL: GROUND DEPLETION AT END OF SEASON																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
	SURFACE INFLOW	SURFACE INFLOW	IMPORT	TATION	SUBTOTAL	OUTFLOW	OUTFLOW	OUTFLOW	EXPORT	OF	APPLIED	TATION					TOTAL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											

\* INCLUDES TOTAL CONSUMPTIVE USE OF PHREATOPHYTES.

Santa Paula Basin. Santa Paula Basin lies between Fillmore Basin on the east and the Oxnard Forebay and Mound Basins on the west. The surface area of the basin, which for study purposes was defined by the extent of the alluvium, is about 13,520 acres. Surface elevations in the Santa Clara River channel vary from about 280 feet above sea level at the eastern extremity of the basin to about 140 feet at the westerly limit. Surface waters drain westerly in the river channel and southerly in Santa Paula Creek, a principal tributary.

Water-bearing formations in Santa Paula Basin include Recent and Pleistocene alluvium having a maximum depth of about 200 feet, underlain by the older San Pedro formation which extends to depths as great as 4,000 feet. However, aquifers of the San Pedro formation in Santa Paula Basin are presently utilized to a maximum depth of about 800 feet. The southerly boundary of Santa Paula Basin is defined by the Oak Ridge fault. The Saticoy fault, which is probably either a branch or an extension of the Oak Ridge fault, separates Santa Paula Basin and the Oxnard Forebay Basin. The boundary between Santa Paula and Mound Basins is defined by an abrupt change in slope of the ground water surface, similar to those described between Piru and Fillmore Basins and between Fillmore and Santa Paula Basins. Geologic section G-G' on Plate 12-A shows the major geologic features of the basin.

Ground water in Santa Paula Basin is generally unconfined, although a localized pressure condition does prevail in the alluvium in the westerly and northwesterly portions of the basin. Ground water generally moves in a southwesterly direction in conformity with the slope of the ground surface. Water wells in the basin draw from both the alluvium and the underlying San Pedro formation, and yield up to 1,500 gallons per minute, with a probable average yield of about 700

gallons per minute. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 10 per cent.

Ground water storage in the Santa Paula Basin is replenished by subsurface flow and effluent discharge from Fillmore Basin, by percolation of runoff in the Santa Clara River, Santa Paula Creek, and minor tributary streams, by deep penetration of direct precipitation, and by percolation of the unconsumed portion of water applied for irrigation and other uses. During the period from 1930 to 1941, inclusive, water from Santa Paula Creek was spread at grounds operated by the Santa Clara Water Conservation District near Santa Paula. This practice was abandoned in 1941, however, because of the prevailing high ground water levels. Disposal of ground water in Santa Paula Basin is effected by pumped extractions to meet requirements of irrigated and urban lands overlying and adjacent to the basin, by exportation, by consumptive use of phreatophytes, by subsurface flow and effluent discharge to Oxnard Forebay Basin, and by subsurface flow to Mound Basin.

Since the net use of ground water in Santa Paula Basin is relatively small in comparison with the magnitude of water supplies available for recharge, historical basin storage depletion has been relatively small. It was estimated that in the fall of 1951 the basin storage had been depleted about 22,600 acre-feet, which is the maximum of record. Examination of Plate 20 shows that over the period of record there was a maximum fluctuation in the water level at key well number 3N/21W-20M1 of only about 35 feet. The relationship between elevations of the ground water surface at this well and ground water storage depletion in Santa Paula Basin is shown on Plate 21.



Within Santa Paula Basin, measured historical change in ground water levels has been entirely in the alluvium. However, immediately to the north of the alluvium defining Santa Paula Basin, the San Pedro formation outcrops on the surface over an area of about 7,900 acres. Since it is indicated that there is hydraulic continuity between the alluvium and the underlying and adjacent San Pedro formation, it is probable that there has been change in ground water storage in the San Pedro formation in the area of outcrop. Lack of well log data and ground water level measurements precluded sufficient determination of physical characteristics of the San Pedro formation adjacent to Santa Paula Basin to estimate change in ground water storage.

Based on available data, and for reasons similar to those cited in the cases of Piru and Fillmore Basins, it is believed that utility of Santa Paula Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

The seasonal results of the monthly hydrologic analysis of Santa Paula Basin are summarized in Table 14. This analysis was made without regard to the undetermined change in ground water storage in the outcrop area of the San Pedro formation north of the basin. The derived values of surface outflow from Santa Paula Basin to Oxnard Forebay Basin, therefore, are in error by the amount of recharge to the San Pedro formation in the outcrop area. In the hydrologic study, items of surface and subsurface flow from Fillmore Basin were taken from the corresponding items of outflow in the analysis for Fillmore Basin presented in Table 13. Additional surface inflow to Santa Paula Basin comprised measured runoff in Santa Paula Creek at the gaging station near Santa Paula, adjusted for upstream diversion. Minor

tributary surface inflow was estimated by correlation with the measured flow of Hopper Creek. It was assumed that the spreading grounds on Santa Paula Creek did not operate during the period of study. Effluent discharge across the Saticoy fault and into Oxnard Forebay Basin was estimated from the determined correlation between measured rates of discharge and slope of the ground water surface. Subsurface outflow to Oxnard Forebay Basin was estimated by means of the rising water method. As may be noted on Plates 14-B, 15-B, and 16-B, there is a sharp increase in slope of the ground water surface from Santa Paula Basin to Mound Basin. The slope from Santa Paula Basin to Mound Basin indicates subsurface flow from the former to the latter. Geologic investigation indicates that this underflow occurs in the San Pedro formation. However, the amount of the underflow was not susceptible to evaluation with the data at hand, and the values for subsurface outflow presented in Table 14 include only the underflow to Oxnard Forebay Basin. Hydrologic and geologic evidence indicates, however, that the unaccounted for subsurface flow may be in the order of 8,000 to 10,000 acre-feet per season. Records were obtained of exports of water to the Oxnard Plain Basin by the Santa Clara Water and Irrigation Company, and to Mound Basin by the Farmers Irrigation Company.

The hydrologic study commenced with an assumed basin storage depletion in the fall of 1936 of 22,600 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study the basin would have first filled in January, 1937, and would have filled or nearly filled each spring thereafter through 1950. From the spring of 1950 until the fall of 1951, disposal of water on the basin would have exceeded recharge, and basin storage would have again been depleted in the amount of 22,600 acre-feet by the fall of 1951.

TABLE 14

ESTIMATED SEASONAL STORAGE DEPLETION IN SANTA PAULA BASIN DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

SEASON	ITEMS OF WATER SUPPLY					ITEMS OF WATER DISPOSAL					CHANGE <sup>B</sup>		
	SUBSURFACE					CONSUMPTIVE USE					IN		
	SURFACE INFLOW	SURFACE INFLOW	PRECIPITATION IMPORT	TATION IMPORT	PRECIPITATION EXPORT	SURFACE OUTFLOW	SURFACE OUTFLOW	PRECIPITATION APPLIED	PRECIPITATION TATION	PRECIPITATION ON BASIN <sup>A</sup>	SUBTOTAL GROUND	WATER DEPLETION AT END OF SEASON	STORAGE
1935-36	246,100	11,200	0	26,900	284,200	229,300	7,200	1,900	13,900	15,700	29,600	268,600	22,600
1936-37	520,100	11,500	400	29,300	561,300	520,700	7,200	1,600	15,600	14,000	29,600	559,100	7,000
1937-38	107,400	11,500	100	16,100	135,100	97,700	7,200	2,100	15,000	14,400	29,400	136,400	4,800
1938-39	70,400	11,500	100	14,600	96,600	61,600	7,200	1,800	15,500	13,800	29,300	99,900	6,100
1939-40	822,000	11,500	1,400	43,400	878,300	832,500	7,200	1,200	13,000	17,200	30,200	871,100	9,400
1940-41	120,700	11,500	1,000	15,100	148,300	116,000	7,200	900	14,000	14,900	28,900	153,000	2,200
1941-42	460,900	11,500	100	30,400	502,900	463,700	7,200	1,100	15,100	14,900	30,000	502,000	6,900
1942-43	395,100	11,500	0	20,000	426,600	387,800	7,200	900	15,400	14,400	29,800	425,700	5,900
1943-44	117,000	11,500	2,200	14,900	145,600	109,200	7,200	700	16,600	13,400	30,000	147,100	4,900
1944-45	117,900	11,500	1,900	13,300	144,600	108,200	7,200	1,000	15,600	13,300	28,900	145,300	6,400
1945-46	94,100	11,500	4,000	14,000	123,600	86,800	7,200	1,400	17,300	12,500	29,800	125,200	7,100
1946-47	23,300	11,500	2,300	8,100	45,200	9,500	7,200	1,400	17,400	10,500	27,900	46,000	8,700
1947-48	20,200	11,500	2,600	9,000	43,300	8,000	7,200	1,600	17,200	11,200	28,400	45,200	9,500
1948-49	24,200	11,500	2,600	13,900	52,200	14,500	7,200	900	16,100	13,800	29,900	52,600	11,400
1949-50	6,300	11,300	1,200	9,100	27,900	2,000	7,200	900	17,200	11,400	28,600	38,700	11,800
1950-51													22,600
AVERAGE FOR BASE PERIOD, 1936-37 THROUGH 1950-51	209,700	11,500	1,400	18,500	241,100	203,200	7,200	1,300	15,700	13,700	29,400	241,100	
AVERAGE FOR WET PERIOD, 1936-37 THROUGH 1943-44	342,800	11,500	400	24,500	379,200	338,700	7,200	1,400	14,700	14,900	29,600	376,900	
AVERAGE FOR DROUGHT PERIOD, 1944-45 THROUGH 1950-51	57,600	11,500	2,400	11,700	83,200	48,300	7,200	1,100	16,800	12,300	29,100	85,700	

A INCLUDES TOTAL CONSUMPTIVE USE OF PHREATOPHYTES.

B ALLUVIUM ONLY.



Mound Basin. Mound Basin is situated north of the Santa Clara River, and lies between the Pacific Ocean on the west and Santa Paula Basin on the east. It has a surface area of about 12,300 acres, varying in elevation from sea level to about 400 feet above sea level. Surface waters of the basin drain southerly to the Santa Clara River and the Pacific Ocean.

Mound Basin consists of from 100 to 500 feet of silts and clays of Recent and Pleistocene age, underlain by gravels, sands, and clays of the San Pedro formation which extends to depths of about 4,000 feet. These formations are extensively folded and faulted. The ground water presently exploited occurs in poorly defined aquifers in the San Pedro formation, and is confined therein by alluvial silts and clays of low permeability. The San Pedro formation has an outcrop area of about 4,400 acres north of the basin.

For study purposes, the areal extent of Mound Basin was taken as the area of the San Pedro formation which is overlain by alluvium. The basin extends westerly into the Ventura Hydrologic Unit, since the San Pedro formation underlies the alluvium at the mouth of the Ventura River. The southerly boundary of the basin, defined by the Santa Clara River channel, represents the southerly limit of lands served by wells deriving water from the San Pedro formation in this portion of the coastal plain. Although geologic data indicate that the San Pedro formation extends under the ocean, sufficient data were not available to determine the location of possible exposures of the pumped aquifers to the ocean, or whether such exposures actually exist. Water levels in wells near the coastal front, drawing from aquifers in the San Pedro formation, react to tidal fluctuations. This effect could result from tidal loading on the formation offshore, and is not necessarily an indi-



cation of hydraulic continuity between the aquifers and the ocean.

Ground water in Mound Basin moves under pressure, generally in a south-westerly direction, from Santa Paula Basin and from the area of outcrop of the San Pedro formation to pumping wells in the basin. Directions of movement of ground water are shown on Plates 14-B, 15-B, and 16-B. Wells in the basin yield from 300 to 1,500 gallons per minute, with an average yield of about 700 gallons per minute. Specific capacities of wells in the basin are estimated to average about 70.

Ground water in Mound Basin is replenished by subsurface inflow from Santa Paula Basin, and by subsurface flow from the outcrop area of the San Pedro formation which receives percolation of direct precipitation and stream flow in minor watercourses. Ground water in the basin is disposed of by pumped extractions to meet overlying domestic and irrigation requirements, and possibly by subsurface outflow to the ocean. Examination of ground water contour maps indicates that there may also be subsurface inflow to and outflow from Oxnard Plain Basin through the San Pedro formation, depending on the relative ground water levels in the Mound and Oxnard Plain Basins. It also appears from study of Plate 16-B, that during drought periods when piezometric levels in Mound Basin are below sea level, sea water may contribute to the seaward extensions of the pumped aquifers.

Water requirements of irrigated lands overlying Mound Basin are satisfied in part by imports of water from Oxnard Forebay Basin by the Alta Mutual Water Company, and from Santa Paula Basin by the Farmers Irrigation Company. The average seasonal amounts of these imports during the base period were about 2,100 acre-feet and 600 acre-feet, respectively.

Uncertainties regarding hydrologic and geologic characteristics precluded direct evaluation of all items of water supply of Mound Basin and disposal thereof during the base period. It is believed, however, that the primary recharge of the basin is by subsurface inflow through the San Pedro formation from Santa Paula Basin, and that the contribution from the outcrop of the San Pedro formation to the north of the basin is of secondary magnitude. The average seasonal extraction of ground water from Mound Basin during the drought period, from 1944-45 through 1950-51, was estimated to have been about 13,500 acre-feet. This includes extractions by the City of Ventura during the seasons of 1947-48, 1948-49, 1949-50, and 1950-51, of about 1,730 acre-feet, 3,240 acre-feet, 2,200 acre-feet, and 4,000 acre-feet, respectively, together with an estimated average extraction of 600 acre-feet per season from the westerly extremity of the basin.

Fluctuations of ground water levels in key well number 2N/22W-8N1 during the period from 1928 through 1952 are shown on Plate 20. It may be noted on the hydrograph that the piezometric level in this well was below sea level from the spring of 1929 to the fall of 1931, and from the spring of 1950 until the fall of 1951, and was also drawn down slightly below sea level for a short period in the spring of 1948. During the wet season of 1951-52 the piezometric level recovered to approximately 18 feet above sea level. Examination of lines of equal elevation of ground water in Mound Basin for the fall of 1951, as shown on Plate 16-B, indicates the presence of a depression in the piezometric surface near the coastal front. The center of this depression was about 16 feet below sea level. It is probable that this depression was formed as a result of heavy pumping from the beach wells of the City of Ventura, and as a result of pumping from the con-

centration of irrigation wells of heavy draft in this vicinity. Formation of this depression lends evidence to a conclusion that the rate of pumping draft exceeded the transmissibility of aquifers extending from Santa Paula Basin, from which subsurface flow appears to be the principal source of ground water supply for Mound Basin. It is probable that during periods when a depression in the piezometric surface prevailed, a portion of the water supply to Mound Basin was obtained from the seaward extension of the aquifers. However, it is believed that sea water intrusion to the wells in the vicinity of the depression did not occur since no increase in chloride concentration in water extracted from the wells was noted.

Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins. Confined aquifers of economic significance in both the Oxnard Plain and Pleasant Valley Basins receive a large portion of their water supply from unconfined ground water in Oxnard Forebay Basin, which in turn is principally replenished by water of the Santa Clara River. Because of the hydraulic continuity between the three basins, they are discussed together in this section. Their relative locations are shown on Plate 11. The three basins comprise a total area of about 76,480 acres, of which Oxnard Forebay Basin occupies about 6,170 acres, Oxnard Plain Basin about 46,460 acres, and Pleasant Valley Basin about 23,850 acres. Ground surface elevations vary from about 60 feet to 150 feet above sea level in Oxnard Plain Basin, and from about 15 feet to 240 feet in Pleasant Valley Basin. Surface waters course westerly and south-westerly to the ocean in the Santa Clara River, Calleguas Creek, and several minor streams and artificial drainage channels.

Water-bearing formations in the three basins consist princi-



pally of alluvium of Recent and Upper Pleistocene age, and of the underlying San Pedro formation of Lower Pleistocene age. In Oxnard Forebay Basin the aquifers primarily utilized are sands and gravels of the Recent and Upper Pleistocene alluvium. In Oxnard Plain Basin, the principal aquifer is a zone of sand and gravel lenses in the Upper Pleistocene alluvial deposits. This zone has been designated and will hereinafter be referred to as the "Oxnard aquifer". A second aquifer, the Fox Canyon member of the San Pedro formation is in contact with the base of the alluvium in Oxnard Forebay Basin, and underlies but is probably hydraulically separated from the alluvium in the Oxnard Plain and Pleasant Valley Basins. This aquifer is utilized only to a minor extent in the Oxnard Forebay and Oxnard Plain Basins, but supplies most of the water to users in Pleasant Valley Basin. In Pleasant Valley Basin, ground water is also obtained from sand and gravel lenses in Recent and Upper Pleistocene deposits which do not appear to be connected with the Oxnard aquifer, and to a minor extent from aquifers in the Santa Barbara formation underlying the Fox Canyon aquifer and from fractures and fissures in volcanic rocks along the southeasterly portion of the basin. Well log sections K-K', L-L', and M-M' on Plate 12-B show the structures and relative position of the water-bearing formations and aquifers in the three basins. Depths from ground surface to the bases of these aquifers are shown in Table 11, together with estimated thicknesses thereof.

The boundary of Oxnard Forebay Basin was taken at the Saticoy fault and the Santa Clara River on the north, and around the remainder of the basin's periphery at the limit of the area of unconfined ground water. Oxnard Plain Basin was defined by the boundaries of the Oxnard Forebay and Mound Basins on the north, by that of West Las Posas Basin in the



Calleguas-Conejo Hydrologic Unit on the northeast, and by that of Pleasant Valley Basin on the east and southeast. The basin is bounded by the ocean on the west, but the Oxnard aquifer probably extends beneath the ocean. The boundary between Oxnard Plain and the Pleasant Valley and West Las Posas Basins corresponds to the assumed limit of lands underlain by the Oxnard aquifer. The boundaries of Pleasant Valley Basin on the north, east, and south were taken as the limit of the alluvium. The northeasterly boundary was defined by topographic features.

The Oxnard aquifer of Oxnard Plain Basin is overlain by sediments of low permeability, which separate this economically important aquifer from a semi-perched ground water body of inferior mineral quality in the alluvium near the ground surface. The relatively impermeable sediments result in confinement of water in the Oxnard aquifer. Whether or not there is complete severance of hydraulic continuity between the semi-perched ground water and water in the Oxnard aquifer was not firmly established.

The portions of the Fox Canyon aquifer in both the Oxnard Plain and Pleasant Valley Basins, and aquifers of the Santa Barbara formation in Pleasant Valley Basin, are also confined by sediments of low permeability. As shown on Section K-K' on Plate 12-B, both the Oxnard and Fox Canyon aquifers appear to extend off-shore beneath the capping and relatively impermeable sediments. Absolute geologic evidence that these aquifers are exposed to the ocean is not available. However, off-shore soundings indicate the existence of two submarine canyons incised in the ocean floor, near Port Hueneme and near Point Mugu. These canyons are of sufficient depth to indicate the probability of exposure of the

Oxnard aquifer to the ocean at points as close as one-quarter mile from the coastline. Although there are not sufficient off-shore data to establish the probability of outcrop of the Fox Canyon aquifer in the submarine canyon near Port Hueneme, it appears probable that this aquifer does outcrop in the submarine canyon near Point Mugu. As described hereinafter in this chapter under "Quality of Water", the intrusion of sea water to wells pumping from the Oxnard aquifer in the vicinity of Port Hueneme has been fairly well established.

Ground water occurring in Oxnard Forebay Basin is unconfined, and it is indicated that it moves from the basin under pressure in a southwesterly direction through the Oxnard aquifer to areas of pumping draft in Oxnard Plain Basin. It is also indicated that ground water leaves Oxnard Forebay Basin under pressure and moves in a southerly direction through the Fox Canyon aquifer to Pleasant Valley Basin. The directions of movement of ground water from Oxnard Forebay Basin are shown on Plates 14-B, 15-B, and 16-B. It was observed that during the recent drought period, troughs or depressions were formed in the piezometric surfaces of the Oxnard aquifer in Oxnard Plain Basin, and of the Fox Canyon aquifer in Pleasant Valley Basin. The positions and depths of the troughs varied in accordance with pumping draft from the two aquifers, and with elevation of the ground water surface in Oxnard Forebay Basin. As a result of formation of the troughs, the direction of ground water movement on their seaward sides was reversed, as shown on Plate 16-B. Plate 13, entitled "Diagrammatic Sketch of Oxnard Forebay and Oxnard Plain Basins" shows the relative position of the piezometric surface in the Oxnard aquifer in Oxnard Plain Basin in spring of 1944 and in the fall of 1951, indicating direction of ground water movement

therein under two extreme conditions.

Wells drawing from Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins yield on the average from 900 to 1,100 gallons of water per minute. However, wells drawing on the alluvium in Pleasant Valley yield an average of about 400 gallons per minute. Specific capacity of wells in Oxnard Forebay Basin averages in excess of 200, in Oxnard Plain Basin about 75, and in Pleasant Valley Basin about 40. The estimated weighted average specific yield of water-bearing materials in Oxnard Forebay Basin, in the range of depth between the highest and lowest historic water levels, is approximately 16 per cent.

Ground water storage in Oxnard Forebay Basin is replenished by natural percolation of surface flow in the Santa Clara River, and by percolation of Santa Clara River water which is diverted to the spreading grounds now operated by the United Water Conservation District near Saticoy. Ground water storage in the basin is also replenished by subsurface inflow from Santa Paula Basin, deep penetration of direct precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water in Oxnard Forebay Basin is disposed of by pumped extractions for beneficial consumptive uses of overlying lands, by exportation, by consumptive use of phreatophytes, and by subsurface outflow to the Oxnard Plain and Pleasant Valley Basins.

As has been stated, the Oxnard aquifer of Oxnard Plain Basin is supplied principally by subsurface inflow from Oxnard Forebay Basin. To a lesser degree it receives underflow from West Las Posas Basin. During the recent drought period, when the hydraulic gradient in the Oxnard aquifer on the seaward side of the cited trough was reversed, contribution to the aquifer appears to have been obtained from the ocean. Also,



there may be some exchange of water between the Oxnard and Fox Canyon aquifers in Oxnard Plain Basin, and between the Oxnard aquifer and the overlying semi-perched ground water body. Disposal of ground water in Oxnard Plain Basin is effected by pumped extractions for beneficial uses, by subsurface outflow to the ocean during periods of high piezometric level in the aquifers, and to a minor extent, by effluent discharge through uncapped wells during periods of high piezometric level.

Aquifers in Pleasant Valley Basin are supplied primarily by subsurface inflow from adjacent basins. Such contributions are received through the Fox Canyon aquifer from Oxnard Forebay Basin, and from East Las Posas and Santa Rosa Basins in the Calleguas-Conejo Hydrologic Unit. They are also received from fractured volcanic rocks on the southeast side of the basin. Some replenishment may be received as subsurface inflow from West Las Posas Basin through the Fox Canyon aquifer which crosses beneath the Camarillo Hills. As in the case of the Oxnard aquifer, with the formation of a trough in the piezometric surface in the Fox Canyon aquifer in Pleasant Valley Basin during the recent drought period, it appears that there may have been subsurface inflow through this aquifer from the ocean. Ground water found in the little-used aquifers of the alluvium in Pleasant Valley Basin appears to be replenished principally by subsurface inflow from adjacent hill areas. Disposal of ground water in Pleasant Valley Basin is effected by pumped extractions for beneficial uses, probably by subsurface outflow to the ocean during periods of high piezometric level in the aquifers, and to a minor extent by effluent discharge through uncapped wells during periods of high piezometric level.

It has been stated that during the recent drought period, with



an increase in ground water extractions and a general diminution of water supplies accompanied by lowered ground water levels in Oxnard Forebay, troughs formed in the piezometric surfaces in both the Oxnard aquifer in Oxnard Plain Basin, and in the Fox Canyon aquifer in Pleasant Valley Basin.

In the Oxnard aquifer the trough first appeared in the spring of 1946, at a location about 3 miles inland from the coastline and south-east of the City of Oxnard. This trough subsequently disappeared, but reappeared during the seasons of 1947-48 and 1948-49 during times of heavy pumping draft. Subsequent to the spring of 1949 the trough persisted, with its center substantially below sea level, until the wet season of 1951-52. As ground water levels continued to lower in Oxnard Forebay, and with continuation of heavy pumping draft from the Oxnard aquifer, the trough also deepened and moved inland until in the spring of 1951 its center was from five to six miles from the coastline and about 40 feet below sea level. At that time, in excess of 27,000 acres of land were being supplied with water pumped from the seaward side of the trough, wherein conditions were conducive to the intrusion of sea water. It was estimated that during the seasons of 1949-50 and 1950-51 about 25,500 and 31,800 acre-feet of water, respectively, were extracted from Oxnard Plain Basin from the seaward side of the trough. In excess of 90 per cent of these amounts were extracted from the Oxnard aquifer, with the remainder from the underlying Fox Canyon aquifer through wells perforated in both aquifers. Since the position and depth of the trough varied considerably prior to the spring of 1950, it was not feasible to evaluate ground water extractions on the seaward side of the trough before that time.

Fluctuations of piezometric levels in the Oxnard aquifer at

wells numbers 1N/22W-7D1, 1N/21W-19A1, and 1N/22W-3F4 are shown on Plate 20. A composite hydrograph of water levels at wells numbers 2N/22W-23H1, 2N/22W-23H2, and 2N/22W-23H3, representative of fluctuations in the ground water surface in Oxnard Forebay Basin, is also shown on Plate 20. It may be noted from this hydrograph that ground water levels in Oxnard Forebay Basin were below sea level for a short period in 1951. The relationship between dewatered ground water storage capacity in Oxnard Forebay Basin and elevation of the ground water surface at well number 2N/22W-23H3 is shown on Plate 21. With the present pattern of pumping, the utility of Oxnard Forebay Basin appears to be limited by its probable hydraulic continuity with the ocean through the Oxnard aquifer in Oxnard Plain Basin. In order to maintain a seaward gradient in the piezometric surface in the Oxnard aquifer with minimum pumping draft therefrom, it was estimated that ground water storage depletion in Oxnard Forebay Basin must not exceed 87,000 acre-feet. As shown on Plate 21, elevation of key well number 2N/22W-23H3 would be about 12 feet above sea level with this estimated maximum safe ground water storage depletion.

The trough in the piezometric surface of the Fox Canyon aquifer underlying Pleasant Valley first formed during the drought period in the spring of 1946. By the fall of 1946 its center was more than 10 feet below sea level. The trough disappeared during the winter of 1946-47, but again appeared in the spring of 1947, with its center approaching 20 feet below sea level in the fall of that year. After recovering during the winter of 1947-48, the trough again formed in the spring of 1948, and has persisted until 1953. The maximum depth of the center of the trough below sea level was estimated to have been about 60 feet in August of 1951. The center of the trough, as shown on

Plate 16-B, occurred about four miles southwest of the town of Camarillo. Fluctuations of the piezometric surface in the Fox Canyon aquifer at well number 1N/21W-16A1, which is near the center of the trough, are shown on Plate 20. Also shown on Plate 20 are fluctuations of the piezometric surface in the Fox Canyon aquifer at well number 2N/20W-17J3, which is in the northeasterly portion of the basin near Somis. It may be noted that since the time of first measurement in 1920, the water surface elevation at well number 2N/20W-17J3 has shown a rather persistent decline. It is believed that this is indicative of the perennial lowering of ground water levels in the Fox Canyon aquifer in East Las Posas Basin, which occurrence is described hereinafter in this section. Uncertainties regarding the exact position of the trough in the Fox Canyon aquifer in Pleasant Valley Basin, and inadequate data concerning amounts of water extracted from the several other aquifers supplying overlying lands in the basin, precluded evaluation of the magnitude of extractions from the Fox Canyon aquifer from the seaward side of the trough.

Plates 14-B, 15-B, and 16-B depict the elevation of the ground water surface in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins in the fall of 1936, in the spring of 1944, and in the fall of 1951, respectively. Plate 15-B also shows the approximate extent of the area wherein piezometric levels in the pressure aquifers were above ground surface in the spring of 1944. Delineated on Plate 16-B is the area where piezometric levels were below sea level in the fall of 1951, and underlain by a landward gradient in the piezometric surface, which condition was conducive to intrusion of sea water to the aquifers. The estimated maximum areal extent of lands in the vicinity of Port Hueneme actually underlain by sea water is also delineated on Plate 16-B.

A monthly analysis was made of water supply and disposal in



the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins during the base period, with present conditions of land use and pattern of pumping. In commencing this analysis, it was assumed that ground water storage depletion in Oxnard Forebay Basin in the fall of 1936 was equal to that in the fall of 1951, or about 109,500 acre-feet. Items of water supply to Oxnard Forebay Basin included surface and subsurface outflow from Santa Paula Basin, as shown in Table 14. In addition, a portion of the export of water from Santa Paula Basin, shown in Table 14, was delivered to Oxnard Forebay and Oxnard Plain Basins by the Santa Clara Water and Irrigating Company. An additional source of water supply to Oxnard Plain Basin consisted of underflow from West Las Posas Basin, estimated to have averaged about 600 acre-feet per season. Underflow to Pleasant Valley Basin, principally through the Fox Canyon aquifer from Santa Rosa and East and West Las Posas Basins, and to a lesser extent from fractured volcanic rocks on the southwest side of this basin, constituted an estimated average seasonal supply of about 4,100 acre-feet. Records were obtained of diversions to the Saticoy spreading grounds. Exports of water from Oxnard Forebay Basin to Mound Basin in an average seasonal amount of about 2,100 acre-feet by the Alta Mutual Water Company, and of export of water to West Las Posas Basin from Oxnard Plain Basin by the Del Norte Water Company in an average seasonal amount of about 1,100 acre-feet, were determined from records of these two companies. For purposes of analysis it was assumed that hydraulic continuity does not exist between the confined aquifers in Oxnard Plain and Pleasant Valley Basins and overlying media. Estimates of extractions of water from these confined aquifers were made for the period from 1944-45 through 1951-52. The estimated seasonal extractions that would have been made during the wet period in



the Oxnard Plain and Pleasant Valley Basins, under present conditions of land use and water supply development, were taken as the average of determined extractions during the two seasons of 1944-45 and 1951-52. Subsurface outflow to the ocean through the Oxnard aquifer was estimated from parameters derived from correlation of ground water surface elevations in Oxnard Forebay Basin, and slopes of the piezometric surface and rates of flow in the Oxnard aquifer. It was estimated that with Oxnard Forebay Basin essentially full, subsurface outflow to the ocean in the aquifer would have a maximum rate of about 2,000 acre-feet per month. It was further estimated that the rate of subsurface outflow with the present pattern of pumping and with Oxnard Forebay Basin essentially full would not be materially affected until the rate of pumping draft from Oxnard Plain Basin exceeded 4,300 acre-feet per month. With lowering of ground water levels in Oxnard Forebay Basin and a rate of pumping draft from Oxnard Plain Basin in excess of 4,300 acre-feet per month, it was estimated that the rate of subsurface outflow to the ocean through the Oxnard aquifer would be reduced. The reasonableness of these estimates were substantiated by independent determinations using the slope area method.

The seasonal summary of the monthly hydrologic analysis of the three basins is presented in Table 15. It may be noted from the table that in order to effect hydrologic balance in most seasons, an item of supply designated "undifferentiated supply from other sources" is shown. For seasons prior to 1944-45, the amount of this supply was determined as a differential in solution of the equation of hydrologic equilibrium under estimated historical rather than study conditions. It was then assumed that the derived magnitude of this supply would not have been materially

different under the assumed conditions of the study. For seasons subsequent to the fall of 1944, at which time Oxnard Forebay Basin was filled, both historically and under study conditions, it was assumed that changes in ground water storage in that basin would have occurred under study conditions as they did historically. The undifferentiated supply from other sources was then evaluated as a differential in solution of the equation of hydrologic equilibrium under these assumed conditions.

There are four water sources which probably contribute to the aforementioned "undifferentiated supply from other sources", but from data at hand it was not possible to evaluate the magnitude of the supply from each source: (1) Contribution to the pumped aquifers of Pleasant Valley Basin may occur from perennial change in storage in free ground water areas in adjacent hills, which ground water bodies are believed to be hydraulically connected with the aquifers in the basin. Change in ground water storage in these areas could not be evaluated because of the lack of well log and water level control. (2) During drought periods, and other times of heavy pumping draft, with attendant lowering of piezometric levels and relief in hydraulic pressure in aquifers underlying the Oxnard Plain and Pleasant Valley Basins, it is possible that clays and other relatively impermeable sediments overlying these aquifers could be compacted. Such compaction would result in release of water from the clays and sediments to the underlying aquifers. It is believed that any possible contribution to the water supply from this source is of small magnitude. (3) It was assumed that the principal pumped aquifers in the Oxnard Plain and Pleasant Valley Basins are not hydraulically connected with overlying semi-perched ground water bodies. The presence of extensive beds of clay and other materials of low permeability between

the pumped aquifers and the semi-perched water bodies has been assumed to preclude supply to the pumped aquifers of water applied to the ground surface, direct precipitation, and other surface waters including the semi-perched water. It is conceivable, however, that these separating clay beds are not continuous, and that the pumped aquifers do in fact receive some recharge from overlying waters. It is possible that water supply from this source could be substantial. (4) As described previously, it was estimated that during the seasons of 1949-50 and 1950-51, water in the amounts of 25,500 acre-feet and 31,800 acre-feet, respectively, was pumped in Oxnard Plain Basin, largely from the Oxnard aquifer on the seaward side of the trough. The volume of these extractions was probably replaced by an equal volume of sea water in the seaward extension of the Oxnard aquifer. From examination of maps showing the position of ground water levels in the Fox Canyon aquifer underlying Pleasant Valley Basin, it is believed that there was similar occurrence therein. As mentioned previously, the amount of movement of water from the ocean into the seaward extension of the Fox Canyon aquifer could not be evaluated. It is probable that water supplies from the seaward extensions of the Oxnard and Fox Canyon aquifers are obtained at all times when piezometric levels in the aquifers are below sea level.



TABLE 15

ESTIMATED SEASONAL STORAGE DEPLETION IN OXNARD FOREBAY BASIN DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE IN OXNARD FOREBAY, OXNARD PLAIN, AND PLEASANT VALLEY BASINS

(IN ACRE-FEET)

SEASON	ITEMS OF WATER SUPPLY TO BASINS										ITEMS OF WATER DISPOSAL FROM BASINS										CHANGE IN : GROUND WATER				
	: SUBSURFACE :	: INFLOW :	: OXNARD :	: IMPORT :	: FOREBAY AND :	: PLEASANT VAL- :	: PRECIPIT- :	: TATION :	: UNDIFFER- :	:	: SUBSURFACE :	: SURFACE :	: OUTFLOW :	: EXPORT :	: ON OXNARD :	: NARD PLAIN :	: FOREBAY :	: AND PLEASANT :	: BASIN :	: VALLEY BASINS :	:	: GROUND :	: WATER :	: DEPLETION IN :	: STORAGE :
	: SURFACE :	: INFLOW :	: OXNARD :	: IMPORT :	: FOREBAY :	: PLEASANT VAL- :	: PRECIPIT- :	: TATION :	: UNDIFFER- :	:	: SUBSURFACE :	: SURFACE :	: OUTFLOW :	: EXPORT :	: ON OXNARD :	: NARD PLAIN :	: FOREBAY :	: AND PLEASANT :	: BASIN :	: VALLEY BASINS :	: SUBTOTAL :	: OXNARD :	: FOREBAY :	: END OF SEASON :	:
1935-36	230,500	11,900	1,100	11,400	20,400	275,300	160,200	12,000	2,300	11,800	68,000	254,300	21,000	109,500											
1936-37	520,500	11,900	1,100	11,600	11,600	556,700	435,600	21,600	2,300	11,700	68,000	539,200	17,500	88,500											
1937-38	97,500	11,900	1,700	7,400	34,400	152,900	53,600	23,600	2,600	11,600	68,500	159,900	-7,000	71,000											
1938-39	61,900	11,900	1,300	6,700	46,100	127,900	27,000	23,100	2,700	11,600	68,000	132,400	-4,500	78,000											
1939-40	832,500	11,900	800	21,600	0	866,800	687,600	23,500	1,900	12,100	67,800	792,900	73,900	82,500											
1940-41	116,000	11,900	700	6,900	34,500	170,000	70,800	23,800	3,300	11,500	67,100	176,500	-6,500	8,600											
1941-42	463,700	11,900	600	12,200	4,100	492,500	379,000	23,400	2,200	11,800	67,600	484,000	8,500	15,100											
1942-43	387,700	11,900	500	10,900	0	411,000	299,500	23,500	2,100	11,800	67,500	404,400	6,600	6,600											
1943-44	109,300	11,900	200	6,400	33,900	161,700	69,900	23,500	2,900	11,800	66,600	174,700	-13,000	0											
1944-45	108,200	11,900	500	5,700	38,700	165,000	59,300	9,200	3,800	11,400	90,300	174,000	-9,000	13,000											
1945-46	86,800	11,900	700	5,900	48,800	154,100	43,900	8,800	4,100	11,700	95,600	164,100	-10,000	22,000											
1946-47	9,500	11,900	600	3,700	68,300	94,000	0	3,600	5,100	10,900	97,400	117,000	-23,000	32,000											
1947-48	7,900	11,900	700	4,500	76,800	101,800	0	1,000	4,400	11,200	104,200	120,800	-19,000	55,000											
1948-49	14,400	11,900	400	6,800	56,600	90,100	0	0	3,600	11,800	88,700	104,100	-14,000	74,000											
1949-50	2,000	11,900	200	4,400	81,000	99,500	0	0	4,700	11,200	105,100	121,000	-21,500	88,000											
1950-51																									

AVERAGE FOR

BASE PERIOD,

1936-37 THROUGH

1950-51

203,200

700

8,400

37,100

261,300

152,400

14,700

3,200

11,600

79,400

261,300

AVERAGE FOR

WET PERIOD,

1936-37 THROUGH

1943-44

338,800

1,000

11,100

18,500

381,700

264,200

21,800

2,400

11,700

67,800

367,900

AVERAGE FOR

DROUGHT PERIOD,

1944-45 THROUGH

1950-51

48,300

500

5,300

57,700

123,700

24,700

6,600

4,100

11,400

92,600

139,400



## Calleguas-Conejo Hydrologic Unit

Six major ground water basins have been identified in the Calleguas-Conejo Hydrologic Unit. These basins, designated Simi, East Las Posas, West Las Posas, Conejo, Tierra Rejada, and Santa Rosa, comprise a total area of about 95,390 acres. The remaining lands of the unit are principally underlain by formations of low permeability which do not yield water readily to wells.

Ground water presently of economic importance occurs both in Recent and Pleistocene alluvial deposits, and in sediments and fractured volcanic rocks of Tertiary age. The geology of the water-bearing materials of the Calleguas-Conejo Hydrologic Unit is complex in nature, and in general there is a paucity of available geologic data. Hydrologic data are similarly inadequate in many parts of the unit. With the exception of Simi Basin, the lack of geologic and hydrologic data precluded reliable analysis of underground hydrology. Table 16 summarizes certain physical characteristics of the six major ground water basins in the Calleguas-Conejo Hydrologic Unit.

TABLE 16

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS  
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated: depth from: ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Simi	10,760	8.6	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-700	0-700	Mostly uncon- fined, some confined	400
			Older formations	Fracture zones and permeable lenses	0-400+	---	Essentially unconfined	100
East and West Las Posas	47,820	---	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-200	0-200	Unconfined	400
			San Pedro	Epworth gravels	0-300	0-200	Essentially unconfined	300
				Fox Canyon	0-2,000	200-400	Confined except near outcrop	600
			Santa Barbara	Grimes Canyon	0-2,000	300-1,000	Confined except near outcrop	600

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS  
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent:	Water-bearing formations	Principal aquifers	Estimated:			Condition of: occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
					depth from: ground	thickness of aquifers,	surface of: to base of: aquifers,:		
Conejo	28,930	5	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-60	0-60	---	Unconfined	50
			Tertiary volcanics and older sedimentary rocks	Fracture zones and permeable lenses in sedimentary rocks	1,000±	---	---	Essentially unconfined	50
Tierra Rejada	4,390	7	Tertiary volcanics	Fractured zones	1,000+	---	---	Essentially unconfined	300
Santa Rosa	3,490	5	Recent and Pleistocene alluvium San Pedro	Lenses of permeable sediments Fox Canyon and other permeable lenses	0-200	0-200	0-200	Unconfined	600
			Volcanics	Fractured zones	0-700	0-700	---	Confined and unconfined	600
					1,500+	---	---	Confined and unconfined	600

\* In zone of historic water level change.

Simi Basin. Simi Basin, situated in the northeastern portion of the Calleguas-Conejo Hydrologic Unit, has a surface area of about 10,760 acres, and ranges in elevation from about 700 to 1,100 feet above sea level. Surface runoff in the basin discharges to the west through Arroyo Simi into East Las Posas Basin. This stream is designated Arroyo Las Posas in East Las Posas Basin, and Calleguas Creek in its lower reaches.

Water-bearing materials in Simi Basin consist of alluvial gravels, sands, and clays of Recent and Pleistocene age, having a maximum depth of about 700 feet. The alluvium is underlain and bounded by older consolidated sediments, wherein ground water is found in minor amounts in fractured zones and in permeable lenses of sands and gravels. The base of the alluvium is concave in shape, deepening toward the center from the peripheral margin. Geologic cross sections Q-Q' and R-R' on Plate 12-C depict the structure and shape of the basin. Ground water in the alluvium is generally unconfined, although clay lenses, particularly in the westerly extremity of the basin, cause localized pressure conditions in the ground water body. Wells in the westerly portion of the basin have been known to flow during periods of high ground water. Normally, ground water moves in a westerly direction toward East Las Posas Basin, as shown on Plates 14-C and 15-C. However, during periods of heavy pumping draft and lowered ground water levels, the slope of the ground water surface at the westerly end of the basin is reversed, as shown on Plate 16-C.

Ground water storage in Simi Basin is replenished by percolation of direct precipitation, of the flow of minor streams, and of the unconsumed portion of water applied for irrigation and other uses, and to a limited extent by lateral subsurface inflow from the flanking consolidated formations. Water is imported to the basin by the Tapo Mutual Water



Company from a well field in Tapo Canyon. These wells pump from aquifers in the Santa Barbara formation, which formation is not hydraulically connected to the alluvium in Simi Basin, although surface waters in Tapo Canyon are tributary to the basin. Some recharge to the basin has been effected through minor spreading operations. Runkle Reservoir, with a storage capacity of 100 acre-feet, located on a minor watercourse on the south side of Simi Valley, is utilized for flood control and to regulate releases to spreading grounds downstream from the dam. In general it is believed that spreading operations in Simi Basin have not contributed significantly to ground water replenishment.

Ground water in Simi Basin is disposed of by pumped extractions for use on overlying lands and on lands adjacent to the basin, by consumptive use of phreatophytes, and by effluent discharge and subsurface outflow to East Las Posas Basin. Wells in the basin are estimated to have an average yield of about 400 gallons per minute. Wells drawing from the older formations around the perimeter of the basin, and from the Santa Barbara formation in Tapo Canyon, are estimated to yield an average of about 100 gallons per minute.

The ground water storage capacity of Simi Basin was estimated to be approximately 180,000 acre-feet. In the fall of 1951, estimated ground water storage depletion in the basin was about 31,000 acre-feet, the greatest during the period for which records of ground levels are available. Ground water levels in Simi Basin have exhibited substantial lowering since measurements were first recorded in the late 1920's. As shown by the hydrograph of the water level in key well number 2N/18W-12L3, on Plate 20, ground water levels showed a persistent decline from 1929 to

1941, when in an excessively wet season there was a substantial recovery. Water levels in the basin were then essentially stabilized until 1944-45, when a rapid decline again commenced which persisted through 1951-52. The relationship between elevation of the ground water surface at well number 2N/18W-12L3 and ground water storage depletion in Simi Basin is shown on Plate 21.

The total decrement in ground water storage during the base period was estimated to have been about 21,000 acre-feet, or an average of about 1,400 acre-feet per season. Tributary surface inflow during the period averaged an estimated 5,300 acre-feet per season, including an average import of about 1,400 acre-feet per season by the Tapo Mutual Water Company. Surface outflow, as measured at the gaging station on Arroyo Simi near Simi, averaged 1,100 acre-feet per season during the base period. Subsurface outflow to East Las Posas Basin was estimated by the slope-area method to have been about 100 acre-feet per season. Direct seasonal precipitation on the ground water basin was estimated to have averaged about 13,300 acre-feet. Average seasonal consumptive use of water on lands overlying the ground water basin, and seasonal consumptive use of water from the basin applied on water service areas adjacent to the basin was estimated to have totaled about 18,800 acre-feet. Of this amount, about 7,500 acre-feet per season represents consumptive use of applied water. It should be pointed out that, as described in Chapter III, analysis of records of application of water to principal crops grown in Simi Basin indicate that in certain portions of the basin these crops have subsisted on deficient water supplies. Had adequate applications of water been given to these crops, the foregoing estimated average seasonal consumptive use of applied water of 7,500 acre-feet would have

been increased to an estimated 9,700 acre-feet.

East and West Las Posas Basins. The East and West Las Posas Basins, situated in the northerly portion of the Calleguas-Conejo Hydrologic Unit and west of Simi Basin, have a surface area of about 47,820 acres. Elevation of the basins varies from about 200 feet to more than 1,500 feet above sea level. East Las Posas Basin is drained by Arroyo Las Posas, which passes southwesterly into Pleasant Valley Basin in the vicinity of Somis. Surface runoff in West Las Posas Basin drains westerly through several minor watercourses to Oxnard Plain Basin.

Ground water in East and West Las Posas Basins occurs in Recent and Pleistocene alluvial deposits, and in the San Pedro and Santa Barbara formations. These latter two formations have been folded into east-west trending synclines and anticlines. Alluvium containing ground water in usable quantities comprises an area of about 5,100 acres on the south side of East Las Posas Basin, extending to depths of about 200 feet. Alluvial deposits elsewhere in the two basins are generally of relatively shallow depth, or so high in silt and clay content that little water is yielded to wells. Ground water in the alluvial deposits is generally unconfined.

The principal pumping aquifer in the San Pedro formation is the Fox Canyon member. The Epworth gravels, occurring near the upper limits of the San Pedro formation, comprise a secondary aquifer in this formation. Ground water in usable quantities is obtained from the Grimes Canyon member of the Santa Barbara formation, which underlies the aforementioned San Pedro formation. Sections L-L' and N-N' on Plates 12-B and 12-C show the structure and relative position of the alluvial deposits and the Fox Canyon and Grimes Canyon aquifers. Section P-P' on Plate 12-C



shows the structure and relative position of the foregoing aquifers, together with the Epworth gravels. Ground water found in the Fox Canyon and Grimes Canyon aquifers is confined, except near their outcrop areas. Ground water in the Epworth gravels is generally unconfined. The Fox Canyon aquifer underlies both East and West Las Posas Basins. From analyses of limited subsurface geologic data, it is believed that the Grimes Canyon aquifer underlies much of the area of the two basins. It is also believed that the Fox Canyon and Grimes Canyon aquifers are interconnected over most of East Las Posas Basin. The alluvium and the Epworth gravels are isolated from each other, and from the Fox Canyon and Grimes Canyon aquifers, by sediments of low permeability. Ground water extractions for beneficial use are primarily from the alluvium and the Fox Canyon aquifer in East Las Posas Basin, and almost entirely from the Fox Canyon aquifer in West Las Posas Basin.

The alluvium in East Las Posas Basin is recharged primarily by percolation of flow in Arroyo Las Posas, by percolation of the unconsumed portion of water applied for irrigation and other uses, and by deep penetration of direct precipitation. The Epworth gravels and Fox Canyon and Grimes Canyon aquifers are recharged largely by deep penetration of direct precipitation on outcrop areas, and by percolation of flow in minor streams traversing these outcrops.

Ground water in the Epworth gravels and in the Fox Canyon and Grimes Canyon aquifers is disposed of through pumped extractions to meet consumptive uses of overlying lands and through consumptive use of phreatophytes. Subsurface outflow to the Oxnard Plain and Pleasant Valley Basins constitutes another item of disposal of ground water of the Fox Canyon aquifer. Ground water in the alluvium is similarly disposed of, as



well as by effluent discharge near Somis, where rising water flows into Pleasant Valley Basin. A portion of the unconsumed residuum of water extracted from the Grimes Canyon and Fox Canyon aquifers returns to ground water storage in the overlying alluvium.

As mentioned previously, the alluvium presently exploited by pumping in East Las Posas Basin comprises a surface area of about 5,100 acres. The areas of outcrop of the Fox Canyon aquifer in East and West Las Posas Basins, located along the north side of both basins and the south side of East Las Posas Basin, were estimated to total about 3,320 acres. The Epworth gravels have an outcrop area of about 1,080 acres located along the northerly side of East Las Posas Basin. The Grimes Canyon aquifer outcrops on both the north and south slopes of Oak Ridge with the estimated area of outcrop being about 5,220 acres. The lack of adequate data on subsurface geology precluded evaluation of the magnitude of storage capacity available in either the alluvium or in the underlying older formations. Similarly, it was not possible to evaluate directly the items of water supply and disposal thereof in the two basins.

As shown on Plate 20, ground water levels at key well number 2N/20W-10R1, which is perforated in the Fox Canyon aquifer in East Las Posas Basin, indicate a rather persistent decline from January, 1928 when the well was first measured, until the present time. Although the rate of decline decreased during the wet period, the dry seasons from 1944-45 through 1950-51 accelerated the decline. During the 25-year period of measurement, water levels at this well were lowered approximately 230 feet. Measurements at key well number 2N/21W-16R1, also shown on Plate 20, perforated in the Fox Canyon aquifer in West Las Posas Basin, indicate that the water level lowered about 55 feet during the period from 1927 to

1953. Some recovery was noted in the water level in this well during the wet period. Subsequent to 1946-47, however, water levels rapidly declined. As shown on Plate 20, ground water levels at key well number 3N/19W-29F3, which is perforated in the Epworth gravels, persistently declined from 1929, but with a more moderate rate than indicated for the Fox Canyon aquifer. Available well measurements indicate that water levels in the alluvium are quickly drawn down during periods of drought, and that they recover rather rapidly during wet periods.

The average decrement in ground water storage in East and West Las Posas Basins during the base period was estimated from rather sparse water level and well log control to have been about 5,000 acre-feet per season. This change in storage occurred primarily in the Fox Canyon aquifer, which is believed to supply most of the water used in the two basins. During this period, seasonal consumptive use of applied water was estimated to have averaged about 16,900 acre-feet. A portion of this consumptive use was met by an import from Oxnard Forebay Basin by the Del Norte Water Company in the amount of about 1,100 acre-feet per season. Subsurface outflow from East Las Posas Basin to Pleasant Valley Basin was estimated by the slope-area method to have been about 3,000 acre-feet per season during the base period. Similarly, it was estimated that about 600 acre-feet per season were discharged to Oxnard Plain Basin as subsurface outflow from West Las Posas Basin.

Conejo Basin. Conejo Basin, situated in the south-central portion of the Calleguas-Conejo Hydrologic Unit, has a surface area of about 28,930 acres, and its boundaries conform to those of the Conejo Hydrologic Subunit. Surface elevations vary from about 300 to 2,300 feet above sea level. Surface waters drain primarily in a westerly direction in Conejo Creek and into Santa Rosa Basin.

The water bearing materials of Conejo Basin include volcanic rocks of Miocene age, and sedimentary formations ranging from Cretaceous to Recent in age. The volcanic rocks are weathered and fractured, with the degree of fracturing being greater in some areas than others. All formations except the alluvium are folded and faulted. In general, the alluvium is quite shallow, and ground water in usable quantities occurs primarily in fissures and weathered zones in the volcanic rocks. Some ground water is also found in permeable lenses of sandstones and conglomerates in the Topanga and Modelo formations of Miocene age. Ground water is essentially unconfined, and its movement conforms to the surface slope.

Ground water storage in Conejo Basin is replenished by deep penetration of direct precipitation, by percolation of flow in Conejo Creek and its tributaries, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water is disposed of through pumped extractions to meet requirements of overlying lands, by subsurface outflow to Santa Rosa Basin through the volcanics, by effluent discharge into Santa Rosa Basin, and by consumptive use of phreatophytes. There may also be some direct contribution to the supply of Pleasant Valley Basin by subsurface outflow from Conejo Basin through the volcanic rocks. Because of the irregular pattern of the fracture system, yield of wells in Conejo Basin varies over wide limits. Those wells penetrating large fractures or fissures have been known to yield as much as 1,000 gallons per minute. This, however, is the exception, with the general yield averaging on the order of 50 gallons per minute.

The indeterminate irregularities in the fracture systems found in the volcanic rocks precluded evaluation of total storage capacity in Conejo Basin through use of conventional methods. Furthermore, since only



one well was measured sporadically in the basin over the base period, it was not possible to estimate change in ground water storage. Indications are that ground water levels in Conejo Basin recover quite rapidly during wet periods, and that the present use of ground water from the basin is being met by natural replenishment. It was estimated that seasonal consumptive use of applied water during the base period averaged about 2,600 acre-feet. Of this amount, about 2,300 acre-feet per season were utilized on irrigated lands.

Tierra Rejada Basin. Tierra Rejada Basin, situated north of Conejo Basin and east of Santa Rosa Basin, has a surface area of about 4,390 acres. The boundaries of the ground water basin are the same as those of the hydrologic subunit of the same name. Surface elevations vary from about 600 feet to 1,600 feet above sea level. Surface waters drain to the west to Santa Rosa Basin.

Ground water in Tierra Rejada Basin, as in Conejo Basin, occurs primarily in fissures and fractures of prevailing volcanic rocks of Miocene age. Small areas of the basin on the north and south sides consist of Tertiary formations in which no wells have been drilled. The volcanics extend to depths of about 2,000 feet, and are folded into a westward plunging syncline. Ground water found in the volcanic rocks is generally unconfined, and moves in a westerly direction in conformity with the surface slope. A north-south trending fault near the westerly extremity of the basin results in a differential in water levels across the fault of up to 80 feet. Wells in Tierra Rejada Basin are reported to yield an average of about 300 gallons of water per minute. However, in the periphery of the basin, difficulty has been encountered in obtaining wells of adequate yield.



Ground water storage in Tierra Rejada Basin is replenished by deep penetration of direct precipitation, by percolation of flow in minor watercourses, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Disposal of ground water occurs through pumped extractions to meet consumptive use of overlying irrigation developments, and probably through subsurface outflow across the aforementioned fault to Santa Rosa Basin. About 500 acre-feet of water per season are exported to Santa Rosa Basin from a well in the extreme westerly portion of Tierra Rejada Basin. It is probable that in the past, depletion of ground water storage in the basin has occurred through effluent discharge and consumptive use of phreatophytes at its westerly extremity.

Water level measurements in Tierra Rejada Basin were initiated at the end of the year 1945 by the Ventura County Water Survey. Since that time ground water levels have shown a progressive decline, and measurements indicate that there was little recovery during the wet season of 1951-52. Water level fluctuations in the basin are illustrated by the hydrograph of well number 2N/19W-14D1, shown on Plate 20. Scattered ground water level measurements since 1930 indicate that disposal of ground water from the basin has probably exceeded replenishment thereto. There were, however, insufficient data available to reliably estimate change in ground water storage over the base period. Consumptive use of applied water in the basin during the base period was estimated to have been approximately 500 acre-feet per season.

Santa Rosa Basin. Santa Rosa Basin occupies an area of about 3,490 acres in the central portion of the Calleguas-Conejo Hydrologic Unit, and south of East Las Posas Basin. Surface elevations vary from about

200 feet to more than 400 feet above sea level. The surface drainage is to the west. Conejo Creek passes through the westerly portion of the basin and flows to a confluence with Calleguas Creek in Pleasant Valley Basin.

Santa Rosa Basin is comprised of alluvial deposits on the south side, with the San Pedro formation outcropping along the north side. Both of these formations are underlain by fractured volcanic rocks. The alluvium extends to depths of about 200 feet. The San Pedro formation consists of up to 700 feet of gravels, sands, silts, and clays, and is folded into a syncline as shown on Sections N-N' and P-P' of Plate 12-C. Ground water occurs in sands and gravels of the alluvium, and in the Fox Canyon aquifer of the San Pedro formation, which aquifer can only be traced in the western portion of the basin. Some ground water is also found in limited gravels in the silty portion of the San Pedro formation, as well as in fractures of the volcanic rocks. Ground water in the alluvium, although generally unconfined, does exhibit localized pressure conditions. Ground water in the Fox Canyon aquifer, and in other gravels of the San Pedro formation, is confined except in the outcrop areas. Ground water moves generally to the west toward Pleasant Valley Basin.

Ground water storage in the alluvium of Santa Rosa Basin is replenished by percolation of flow in Conejo Creek and its tributaries, by deep penetration of direct precipitation, by percolation of the unconsumed portion of water applied for irrigation and other uses including that of ground water extracted from the San Pedro formation, and possibly by lateral movement of ground water from volcanics in both Tierra Rejada and Conejo Basins. Ground water storage in the San Pedro formation is recharged by percolation of flow in minor watercourses, by

deep penetration of direct precipitation on its outcrop area along the north side of the basin, and possibly by lateral underflow from the volcanic rocks. Ground water storage is depleted by pumped extractions to meet beneficial consumptive use on overlying lands, by effluent discharge, and by some subsurface outflow to Pleasant Valley Basin. Wells in Santa Rosa Basin are reported to yield as much as 1,200 gallons per minute, with an estimated average yield of about 600 gallons per minute.

Water level fluctuations at key well number 2N/20W-23R1, which is perforated in the alluvium, are shown on Plate 20. It may be noted that although water levels in this well showed substantial recovery during the wet period, there was a net lowering of about 20 feet during the base period. The average decrement in ground water storage in the basin during the base period was estimated to have been about 200 acre-feet per season. The estimated seasonal consumptive use of applied water during the base period was about 3,100 acre-feet. An import from Tierra Rejada Basin in the amount of about 500 acre-feet per season satisfied a portion of this consumptive use. It was estimated that during the base period there was a small subsurface outflow to Pleasant Valley Basin in an amount not in excess of 200 acre-feet per season.

#### Quality of Water

Surface and ground water supplies of Ventura County are generally of good mineral quality and suitable from that standpoint for irrigation and other beneficial uses. Notable exceptions are found in the waters of some minor surface streams and in the low flows of several major streams, as well as in ground waters found in some portions of the County. It has been reported that in certain areas crops have suffered injury



from application of waters containing high boron concentrations. In addition it has been reported that crops in some localities have suffered from excessive soil salinity during drought periods, which is an indication that normal rainfall is a factor in keeping soil salinity within acceptable limits.

In a number of ground water basins in Ventura County, it appears that the average seasonal quantity of dissolved salts added to ground water supplies exceeds the average seasonal quantity removed. Thus an unfavorable salt balance is created which, if continued, may seriously affect the quality of ground water in the basins. Plans for water supply development to eliminate present overdrafts on ground water basins and to satisfy probable future water requirements must also provide sufficient water to maintain a satisfactory salt balance in ground water basins.

The Division of Water Resources is presently conducting a detailed County-wide investigation of water quality and water quality problems in Ventura County, in accordance with sections 229 and 230 of the Water Code. Since results of that investigation will be published in the near future, water quality data and discussion herein are limited to a general presentation of factors which affect the suitability of available water supplies for prevailing beneficial uses.

The following terms are used, as defined, in connection with the discussion of quality of water in this bulletin:

Quality of Water--Those characteristics of water affecting its suitability for beneficial uses.

Contamination--Impairment of the quality of water by sewage or industrial waste to a degree which creates a hazard to public health through poisoning or spread of disease.



Degradation--Impairment of the quality of water due to causes other than disposal of sewage and industrial wastes.

Pollution--Impairment of the quality of water by sewage or industrial waste to a degree which does not create a hazard to public health, but which adversely and unreasonably affects such water for beneficial use.

Mineral Analyses--The quantitative determination of inorganic impurities or dissolved mineral constituents in water.

Complete mineral analyses reported in this bulletin include determination of calcium, magnesium, sodium and potassium, bicarbonate, carbonate, chloride, sulphate and nitrate, fluoride, boron, total dissolved solids, electrical conductance ( $EC \times 10^6$  at  $25^\circ C$ ), per cent sodium, and effective salinity. Partial mineral analyses include determinations of chlorides, bicarbonates, and electrical conductance. In some instances boron determination was included in the partial mineral analysis.

In general, the concentrations of principal constituents determined in a complete mineral analysis are expressed herein as "equivalents per million". Exceptions to this are boron, fluoride, and total dissolved solids. Reporting in equivalents per million was done because ions combine on an equivalent basis rather than on a weight basis, and a chemical equivalent unit of measurement provides a more convenient expression of concentration. This is particularly true when it is desired to compare the composition of waters having variable concentrations of mineral constituents. In the cases of boron, fluoride, and total dissolved solids, concentrations are reported on a weight basis of "parts per million". To convert equivalents per million, or "epm", to parts per million, or "ppm", the concentration in equivalents per million should be multiplied by the equivalent weight of the ion. Equivalent weights of the principal con-

stituents found in water supplies are presented in the following tabulation:

<u>Cation</u>	<u>Equivalent weight</u>	<u>Anion</u>	<u>Equivalent weight</u>
Calcium	20.0	Carbonate	30.0
Magnesium	12.2	Bicarbonate	61.0
Sodium	23.0	Chloride	35.5
Potassium	39.0	Sulphate	48.0
		Nitrate	62.0

Data used to determine the quality of water in Ventura County included 273 complete and 156 partial mineral analyses of surface water, and 1,161 complete and 1,080 partial mineral analyses of ground water.

#### Standards of Quality for Water

The waters of Ventura County are used for irrigation, domestic, and municipal and industrial purposes. Suitability of the waters for each of these uses depends in part upon the amount and kind of dissolved minerals they contain. Water quality criteria and standards for the above named uses are discussed in the following paragraphs:

Irrigation Use. The major criteria used as a guide to judge the suitability of water for irrigation use usually comprise the following: (1) chloride concentration, (2) conductance ( $\text{EC} \times 10^6$  at  $25^\circ\text{C}$ ), (3) boron concentration, and (4) per cent sodium.

(1) Chlorides are present in nearly all waters. They are not considered essential to plant growth, and may be especially harmful in high concentrations as they cause subnormal growing rates and burning of leaves.

(2) Conductance ( $\text{EC} \times 10^6$  at  $25^\circ\text{C}$ ) is an indicator of the total

dissolved solids, and as such, furnishes an approximate indication of the overall mineral quality of the water. For most waters, the total dissolved solids may be approximated by multiplying the conductance by 0.7. The presence of excessive amounts of dissolved salts in irrigation water will result in reduced crop yields and burning of leaves.

(3) Boron in nature is never found in the uncombined or elemental state but occurs in the form of boric acid, or more commonly as borates. This element is essential in small amounts for the growth of many but not all plants. It is, however, extremely toxic to most plants in higher concentration. Limits of tolerance for most irrigated crops vary from 0.5 to 2.0 ppm. Citrus, particularly lemons, is sensitive to boron in concentrations exceeding 0.5 ppm.

(4) Per cent sodium reported in the analyses is the proportion of the sodium cation to the sum of all cations, and is usually obtained by dividing sodium by the sum of the amounts of calcium, magnesium, and sodium, all expressed in equivalents per million, and multiplying by 100. Water containing a high per cent sodium has an adverse effect upon the physical structure of the soil by dispersing the soil colloids and making the soil "tight", thus retarding movement of water through the soil, retarding the leaching of salts, and making the soil difficult to work. When potassium is present in water in significant amounts, its effect on soils is similar to sodium.

The following excerpts from a paper by Dr. L. D. Doneen, of the Division of Irrigation of the University of California at Davis, may assist in interpreting water analyses from the standpoint of their suitability for irrigation:

"Because of diverse climatological conditions, crops, and soils



in California, it has not been possible to establish rigid limits for all conditions involved. Instead, irrigation waters are divided into three broad classes based upon work done at the University of California, and at the Rubidoux, and Regional Salinity Laboratories of the United States Department of Agriculture.

"Class 1. Excellent to Good--Regarded as safe and suitable for most plants under any condition of soil and climate.

"Class 2. Good to Injurious--Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

"Class 3. Injurious to Unsatisfactory--Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

"Tentative standards for irrigation waters have taken into account four factors or constituents, as listed below:

<u>Factor</u>	<u>Class 1 excellent to good</u>	<u>Class 2 good to injurious</u>	<u>Class 3 injurious to unsatisfactory</u>
Conductance (EC x 10 <sup>6</sup> at 25°C)	Less than 1,000	1,000-3,000	More than 3,000
Chloride, epm	Less than 5	5-10	More than 10
Per cent sodium	Less than 60	60-75	More than 75
Boron, ppm	Less than 0.5	0.5-2.0	More than 2.0

(End of quotation)

The values shown in the foregoing tabulation should be used as a guide only, since permissible limits vary widely with different crops, soils, and climatic conditions. Actual practice in Ventura County indicates that waters rated as class 2 and 3 by the foregoing standards particularly in regard to conductance, are successfully used to irrigate



citrus. Accordingly, a new method of calculating salinity of irrigation water together with revised standards therefore has been suggested by Dr. Doneen as follows:

"This proposed standard for total salts of an irrigation water is based on the premise that the salts will accumulate in the soil due to evaporation from the soil surface and water used by the plants in transpiration. Plants usually remove only a small percentage of the total salts occurring in the irrigation water. As the soil solution becomes concentrated certain salts will precipitate. Because of the low solubility, the first to precipitate will be calcium carbonate, followed by magnesium carbonate and finally by calcium sulfate. These salts will not produce a saline soil. Other salts normally occurring in irrigation water in any significant concentration are extremely soluble and accumulate in the soil solution as salines. These salines are listed as 'effective salinity'. Therefore, calcium and magnesium carbonates and calcium sulfate should not be considered in establishing standards for total salinity as is now the practice in the use of electrical conductance, total parts per million or milliequivalents per liter concentration."

Using this method, Dr. Doneen has tentatively suggested the following criteria of effective salinity for classification of irrigation waters under three soil conditions:

<u>Soil conditions</u>	<u>Class 1 excellent to good</u>	<u>Class 2 good to injurious</u>	<u>Class 3 injurious to unsatisfactory</u>
	<u>Effective salinity, in epm</u>		
Little or no leaching of the soil may be expected	Less than 3	3-5	More than 5
Some leaching, but restricted. Deep percolation or drainage slow	Less than 5	5-10	More than 10
Open soils. Deep percolation of water easily accomplished	Less than 7	7-15	More than 15

Review of the soil survey of Ventura County made by the United States Department of Agriculture indicates that most of the irrigable lands in the County are classified as open soils. For this reason, criteria for soils of this condition will apply throughout this discussion unless otherwise stated.

Domestic and Municipal Use. Probably the most widely used criteria for determining the suitability of water for domestic and municipal use are the "United States Public Health Service Drinking Water Standards, 1946". The individual standards considered pertinent to the discussion presented hereinafter are shown on Table 17.

TABLE 17

UNITED STATES PUBLIC HEALTH SERVICE  
DRINKING WATER STANDARDS  
1946

Constituent	: :	Should not exceed ppm
Total Solids		500 (1,000 permitted) <sup>(a)</sup>
Magnesium (Mg)		125
Chloride (Cl)		250
Sulphate (SO <sub>4</sub> )		250
Zinc (Zn)		15
Fluoride (F)		1.5 <sup>(b)</sup>

(a) Where alternate source of water unavailable.

(b) Limits for this constituent mandatory; for others recommended.

Total hardness is a significant factor in the determination of the suitability of a water for domestic and municipal use. It is caused principally by compounds of calcium and magnesium, although other sub-

stances such as iron, manganese, aluminum, barium, silica, strontium, and free hydrogen contribute to total hardness. The effect of hardness in water is primarily economic, in that its presence requires an increased use of soap, which it coagulates to form an insoluble precipitate. It also causes formation of scale which tends to reduce the efficiency of boilers and plumbing systems. With suitable treatment, however, hardness can readily be removed or reduced to acceptable limits. Water containing 100 ppm or less of hardness (as  $\text{CaCO}_3$ ) are considered as "soft" herein; those containing 101 to 200 ppm are considered "moderately hard"; and those with more than 200 ppm are considered "very hard".

Industrial Use. The foregoing standards for domestic and municipal use are considered applicable for prevailing industries in Ventura County.

#### Quality of Surface Water

The mineral quality of surface water in Ventura County is extremely variable both areally and with the rate of stream flow. At times of low flow in many streams the water contains excessive mineral concentrations, particularly of boron and sulphate. Because of the variability in quality of surface water, each hydrologic unit is discussed separately herein. Representative analyses showing mineral quality of the waters in principal streams, and variations in quality with rate of flow, are presented in Table 18. The locations of surface sampling stations for which analyses are shown in Table 18 are delineated on Plate 7, entitled "Stream Gaging and Water Sampling Stations".

Ventura Hydrologic Unit. Waters of Matilija Creek, Coyote Creek, and the Ventura River above Foster Park, generally are of good quality and



suitable for prevalent beneficial uses. Although at low flow stages in Matilija Creek the water contains boron concentrations as high as 6.5 ppm, water stored in Matilija Reservoir in May, 1952, showed only 0.34 ppm of boron. Below Foster Park, waters containing excessive concentrations of sulphates and boron are added to the Ventura River by tributaries, particularly by Canada Larga, even at relatively high rates of flow. As a result of these tributary inflows, water of Ventura River below Foster Park is generally considered unsuitable for domestic purposes, and of class 2 to class 3 for irrigation use.

Santa Clara River Hydrologic Unit. Water in the Santa Clara River in Ventura County is generally of good mineral quality for irrigation and other prevailing beneficial uses. However, it is seldom of excellent quality except during periods of relatively high flow. Effective salinity rarely exceeds 10 epm even during times of low flow. Mineral analyses indicate that water flowing in Santa Paula Creek is of good to excellent mineral quality even during low flow stages. Water of Sespe Creek is generally of good to excellent mineral quality for irrigation, and suitable for domestic use, for flows in excess of 60 second-feet near its mouth. For flows less than 60 second-feet, analyses indicated that water contains concentrations of boron varying from 0.7 to over 4 ppm, thus rendering it marginal to unsatisfactory for irrigation use. Mineral analyses indicate that water flowing in Hopper Creek is generally unsatisfactory for irrigation use, except during periods of flood flow. Like Sespe Creek, water flowing in Piru Creek contains high concentrations of boron at low flow stages. Based upon many analyses, it was concluded that flows must exceed 200 second-feet at the U.S.G.S. gaging station near the town of Piru before the boron concentration is



reduced to values of 1.0 ppm or less. From the standpoint of its other mineral constituents, Piru Creek water is of good quality for irrigation purposes at all flow stages, although at low flow stages total solids and sulphate concentrations exceed the prescribed limits for domestic use. Waters of some of the minor tributaries of the Santa Clara River contain high concentrations of sulphate. However, their effect on the general mineral quality of the river water is considered to be negligible.

Calleguas-Conejo Hydrologic Unit. The mineral quality of surface water in this hydrologic unit varies considerably. It is generally unsuitable for irrigation or other prevailing beneficial uses during low flow stages, but during flood stages the quality is generally good. Typical examples of poor mineral quality in surface streams at low flow stages in this hydrologic unit are shown in analyses of waters from Arroyo Simi and Tapo Creek, which contained dissolved solids of 7,057 and 4,122 ppm, respectively.

Malibu Hydrologic Unit. There is a paucity of data concerning the mineral quality of surface water in the Malibu Hydrologic Unit. However, single available analyses for Big and Little Sycamore Creeks indicate that these waters are suitable for prevailing beneficial uses.

TABLE 18

## SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY

STREAM AND STATION NUMBER	DATE OF SAMPLE	DISCHARGE, IN SECOND-Feet	CONDUCTANCE, (EC x 10 <sup>6</sup> ) AT 25°C	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL				EFFECTIVE: PER CENT
				Ca	Mg	Na	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>	FLUOR--	BORON--	DISSOLVED:	SALINITY		
VENTURA HYDROLOGIC UNIT																		
VENTURA RIVER 42-0.7	2-25-53 <sup>B</sup>	10 <sup>C</sup>	2583	7.24	3.78	15.7	0.16	0	6.12	7.34	13.8	0	--	1.9	1619	19.6	59	
CANADA LARGA 42-4.8-0.1	1-16-52 <sup>B</sup>	300 <sup>C</sup>	1618	9.38	5.66	6.09	0.26	0	3.72	14.55	1.92	0.30	0.1	0.4	1444	12.0	29	
COYOTE CREEK 42-6.1-0.2	8-1-52	0.5 <sup>C</sup>	3662	8.21	13.19	18.40	0.28	0	5.36	29.20	5.94	0.09	--	1.2	2775	31.9	46	
	3-16-52	200 <sup>C</sup>	452	2.70	1.25	0.65	----	0	2.49	1.71	0.51	0.01	--	0.1	272	1.9	14	
SAN ANTONIO CREEK 42-8.1-0.2	8-1-52 <sup>B</sup>	3 <sup>C</sup>	658	4.14	2.22	1.43	0.04	0	4.12	2.97	0.48	0.04	--	0.1	457	3.7	18	
	3-15-52	FLOOD FLOW	302	1.97	0.93	0.30	----	0	1.68	1.34	0.20	0.08	--	0.2	226	1.2	9	
VENTURA RIVER 42-10.6	5-25-52	1 <sup>C</sup>	1545	9.85	4.00	3.78	----	0	5.40	9.38	2.95	0.27	--	0.2	1195	7.8	21	
	5-27-52	3 <sup>C</sup>	824	4.80	2.27	1.93	----	0	2.92	5.62	0.45	0	--	0.3	665	4.2	21	
MATILAJA CREEK 42-15.8-0.2	12-5-51	2 <sup>C</sup>	1528	7.40	2.80	4.08	----	--	4.00	6.60	3.98	Tr.	--	2.6	924	6.9	29	
REVOLON SLOUGH 44-2.1-1.7	3-15-52	FLOOD FLOW	788	4.96	2.62	0.90	----	0.34	3.01	4.68	0.48	0.02	--	0.2	545	3.5	11	
	1-14-53 <sup>B</sup>	6 <sup>C</sup>	7874	13.3	20.0	69.6	0.22	0	7.20	77.6	18.2	0.17	--	5.1	7109	89.8	68	
SANTA CLARA RIVER 43-4.6	8-5-52	0.5 <sup>C</sup>	2700	12.93	7.85	14.15	0.26	0	4.44	27.20	2.91	0	--	0.6	1903	22.3	40	
	1-14-53 <sup>B</sup>	100 <sup>C</sup>	1397	6.90	3.62	5.22	0.12	0	4.28	9.17	1.75	0.07	--	0.6	1022	9.0	33	

TABLE 18 (CONTINUED)

## SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY

STREAM AND STATION NUMBER	DATE OF SAMPLE	DISCHARGE, IN SECOND-FEET	CONDUCTANCE, (EC x 10 <sup>6</sup> )	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL				EFFECTIVE: PER			
				CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>	FLUORIDE, IN PPM	BORON, IN PPM	DISSOLVED SOLIDS, IN PPM	SALINITY IN EPM	SODIUM IN PPM	PERCENT SODIUM	PERCENT SODIUM	PERCENT SODIUM	PERCENT SODIUM
SANTA PAULA CREEK 43-15.9-0.8	1-12-53 <sup>B</sup>	8 <sup>C</sup>	840	4.50	1.89	2.52	0.04	0	3.56	4.21	0.90	0	---	0.1	564	4.4	38				
43-15.9-4.5	3-15-52	1600 <sup>C</sup>	402	2.62	0.77	0.68	---	0	1.85	1.98	0.25	0.01	---	0.3	282	1.4	17				
SESPE CREEK 43-22.3-5.4	3-30-46 <sup>D</sup>	8000	---	1.80	0.66	0.26	---	0	1.77	0.83	0.14	0	---	0	---	0.9	10				
2- 7-51 <sup>E</sup>		3.1	1350	5.64	2.30	5.91	0.07	0	3.44	5.95	4.51	0.01	---	4.1	848	8.3	42				
HOPPER CREEK 43-29.7-1.0	3-15-52	4000 <sup>C</sup>	517	4.36	1.13	0.37	---	0	1.72	3.96	0.23	0.01	---	0	411	1.5	6				
5-22-52		2.5 <sup>C</sup>	2060	8.06	8.28	9.78	---	0	6.06	19.26	1.32	0.03	---	0.4	1850	18.1	38				
PIRU CREEK 43-32.1-1.1	8- 4-52	5 <sup>C</sup>	1610	6.63	5.56	6.27	0.15	0	4.34	12.60	1.70	0	---	1.6	1219	12.0	34				
43-32.1-1.3	3-30-46 <sup>D</sup>	1570	---	2.55	1.48	1.17	---	0	2.16	3.12	0.25	0	---	0.1	---	2.6	23				
11-21-46 <sup>D</sup>		200	---	4.20	1.97	1.52	---	0	2.28	5.29	0.34	0.02	---	1.0	---	3.5	20				
43-32.1-4.0	3-15-52	1000 <sup>C</sup>	975	5.32	4.43	1.26	---	0	2.15	8.41	0.31	0.15	---	0.2	768	5.7	11				
2- 7-51 <sup>E</sup>		5.0	1880	8.63	6.66	7.39	0.12	0	5.60	15.11	1.97	0.02	---	2.1	1420	14.2	32				
SALT CREEK 43-37.6-0.4	3-18-52 <sup>B</sup>	5 <sup>C</sup>	4854	22.8	37.8	20.8	0.35	0	5.92	73.1	1.69	0.24	---	0.7	5755	59.0	25				
SANTA CLARA RIVER 43-38.1	9-19-51 <sup>B</sup>	0.7	3623	12.35	12.91	8.60	---	0	4.96	24.08	6.48	0.01	0.6	1.0	2960	21.5	25				

TABLE 18 (CONTINUED)

SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY<sup>A</sup>

STREAM AND STATION NUMBER	DATE OF SAMPLE	DISCHARGE, IN SECOND- FEET	CONDUCTANCE, (EC X 106 AT 25°C)	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL EFFECTIVE: PER			
				CA	MG	NA	K	CO3	HCO3	SO4	CL	NO3	FLUOR- IDE,	BORON, IN PPM	DISSOLVED SOLIDS, IN PPM	SALINITY : CENT- IN EPM	SODIUM IN PPM
				CALLEGUAS-CONEJO HYDROLOGIC UNIT													
CALLEGUAS CREEK 44-6-5	3- 7-52	2500	644	4.36	1.93	1.03	----	0	2.11	4.76	0.56	0.02	----	0.1	506	3.0	14
	3-15-52	130C	1313	9.54	3.48	2.25	----	0	3.23	11.40	0.90	0.07	----	0.3	1058	5.7	15
CONEJO CREEK 44-7-9-3.0	3-15-52	1500C	208	1.29	1.61	0.10	----	0	1.76	1.00	0.25	0	----	0	185	1.2	3
	12- 2-52	4C	243	0.98	0.67	0.84	0.03	0	1.64	0.30	0.39	0.18	----	0.2	214	0.9	33
ARROYO SIMI 44-12-2-9.4-4.7	3-15-52	2000C	1649	15.51	3.83	1.22	----	0	2.45	17.32	0.65	0.04	----	0.3	1453	5.0	6
	4-16-52B	0.1	6757	33.88	30.58	40.20	0.64	0	8.00	71.09	23.12	0.24	----	4.1	7057	71.4	38
TAPO CREEK 44-12-2-9.4-8.0-2.5	3-15-52	75C	2010	17.56	5.20	2.69	----	0	2.49	21.50	0.98	0.21	----	0.3	1809	7.9	11
	12-12-51	0.3	2730	25.60	6.20	3.48	----	-	2.82	29.73	2.06	0.08	1.0	0.8	4122	9.7	10

<sup>A</sup> ANALYSIS BY PACIFIC CHEMICAL CONSULTANTS, UNLESS OTHERWISE NOTED.<sup>B</sup> ANALYSIS BY DIVISION OF WATER RESOURCES.<sup>C</sup> ESTIMATED.<sup>D</sup> ANALYSIS OBTAINED FROM SANTA CLARA WATER CONSERVATION DISTRICT.<sup>E</sup> ANALYSIS BY U.S. GEOLOGICAL SURVEY, WATER QUALITY BRANCH; UNPUBLISHED RECORDS, SUBJECT TO REVISION.



## Quality of Ground Water

Mineral quality of waters in ground water basins of Ventura County is generally satisfactory for domestic, municipal, industrial, and irrigation uses. However, for domestic, municipal, and industrial uses, the ground waters are almost without exception rated as "very hard". In some areas the ground water contains concentrations of sulphates and dissolved solids which are considered excessive for domestic, municipal, and industrial uses, and in a few areas excessive boron concentrations and effective salinities render the ground water injurious or unsatisfactory for irrigation use.

In the investigation of water quality and water quality problems in Ventura County, more than 2,000 mineral analyses of ground water were studied. Table 19 shows representative analyses of ground water in each of the major ground water basins of the County, with exception of Lower Ventura River Basin. The locations of wells sampled and for which analyses are presented in Table 19 are shown on Plate 11, entitled "Ground Water Basins". Ground water quality in each of the hydrologic units is discussed separately in the ensuing paragraphs.

Ventura Hydrologic Unit. Ground water in Upper Ojai Basin contains total dissolved solids generally less than 700 ppm and effective salinities less than 6 epm. In the extreme easterly portion of the basin, toward Sisar Creek, there is a small area of poor quality ground water containing 2,000 to 3,000 ppm of dissolved solids, and boron concentrations up to 1.5 ppm.

In Ojai Basin, ground waters are generally suitable for irrigation, domestic, municipal, and industrial uses. Total dissolved solids range from about 450 to 1,100 ppm, and effective salinities are generally

less than 6 epm. Comparison of mineral quality found in 1950-51 with quality reported in 1930-31 suggests an increase in total dissolved solids in ground water in Ojai Basin in the 20-year period. This increase indicates that an adverse salt balance existed during the 20-year period, but does not necessarily indicate that an adverse salt balance would exist over a period of mean water supply and climate.

In the Upper Ventura River Basin, the ground water contains dissolved solids generally less than 1,000 ppm and boron generally less than 0.5 ppm. Ground water in Lower Ventura River Basin, as previously described, is not presently utilized.

Santa Clara River Hydrologic Unit. Ground water found in the several basins in the Santa Clara River Hydrologic Unit does not exhibit a consistent pattern of water quality, varying considerably among the basins and within a given basin in accordance with the time of year, relative wetness of the season, and position of ground water levels. Higher concentrations of salts and boron are usually found in the ground waters during drought periods than during wet periods.

Ground water in Piru Basin contains total dissolved solids ranging from 800 to 3,400 ppm, with many waters exceeding 1,000 ppm. Effective salinities vary from about 6.7 to over 60 epm, although in most cases they are less than 12. Boron concentrations are generally high, exceeding 0.5 ppm in nearly all water samples analyzed, and approaching 1.0 ppm in ground water sampled near the mouth of Piru Creek. Some wells located in the extreme southerly portion of the alluvium in Piru Basin yield water with high concentrations of dissolved solids and boron, and with effective salinity unsuitable for irrigation uses. These poor

quality ground waters may originate in the Tertiary formations which underlie and flank the alluvium in this area.

Ground water in Fillmore Basin is generally of class 1 to class 2 quality for irrigation use with dissolved solids averaging about 1,200 ppm and effective salinity ranging from 0.9 to 42.7 emp and averaging about 9.3 epm. Boron concentrations average about 0.7 ppm. In the northwesterly part of the basin, ground water quality is generally good, with total dissolved solids ranging from 500 to 600 ppm and with boron concentrations generally less than 0.5 ppm. Effective salinity averages less than about 5 epm. Ground water from wells in the southerly portion of the basin, in the vicinity of the Oak Ridge fault, is affected by poorer quality water emanating from tertiary formations on the south, and is generally unsuitable for irrigation use.

Ground water in Santa Paula Basin varies from class 1 to class 3 for irrigation use, with dissolved solids generally ranging from about 600 to 3,600 ppm, and effective salinity from about 4.5 to 18 emp, with a general average of the order of 12 epm. Marginal values of boron have been found in ground water throughout the basin, with concentrations varying from about 0.1 to 2.8 ppm.

Ground water pumped from the Mound Basin is of class 1 to class 2 quality for irrigation use. Some of the water is slightly in excess of the maximum standard for domestic use with regard to dissolved solids and sulphate content. Total dissolved solids generally range from about 700 to 1,300 ppm, and the effective salinity varies from about 7 to 11 epm. Boron concentrations are generally less than 0.5 ppm. As described previously, geologic investigation has indicated that the San Pedro formation, which is the principal pumped aquifer of Mound Basin,



extends into the Ventura Hydrologic Unit and underlies Lower Ventura River Basin. This appears to be substantiated by a similarity between the character and quality of water derived from wells drilled in the vicinity of Ventura and ground water obtained in the remainder of the Mound Basin.

In Oxnard Forebay Basin, total dissolved solids in the ground water range from 840 to about 2,100 ppm, with the boron concentrations in the vicinity of 0.3 to 1.1 ppm. Effective salinity ranges from 7 to 15 epm.

The quality of ground water derived from the Oxnard aquifer of the Oxnard Plain Basin is comparable in mineral quality to ground water of the Mound Basin. Some of the water pumped from wells located near the Oxnard Forebay Basin shows dissolved salts higher than found in ground water from the remainder of the Oxnard Plain Basin. Water from certain wells in the vicinity of Port Hueneme has shown of recent times rapidly increasing chloride concentrations. The cause of this chloride degradation is believed to be sea water intrusion, as will be discussed in a later section. Water derived from the semi-perched ground water body of the Oxnard Plain Basin is of class 2 to class 3 quality for irrigation use and is generally unsuitable for domestic use. The dissolved solids content in the waters of the semi-perched ground water body is in excess of 1,650 ppm, while the effective salinity is greater than 11.5 epm and values exceeding 20 epm are not uncommon. Table 20 presents the results of analyses of ground water in the semi-perched ground water body in Oxnard Plain Basin, as obtained from samples taken at selected points in the drainage system in the area. The locations of the sampling stations are shown on Plate 7, entitled "Stream Gaging and Water Sampling Stations".

Ground water in Pleasant Valley Basin is derived from several



aquifers of the San Pedro and Santa Barbara formations, from alluvium, and to a lesser extent, from fractured volcanic rocks along the east side of the basin. In the aquifers of the San Pedro and Santa Barbara formations, the waters are class 1 to class 2 for irrigation use with total dissolved solids in concentrations ranging from about 450 to about 1,500 ppm and boron content generally less than 0.5 ppm. While the character of the waters derived from these deposits is extremely variable, calcium is generally the most important cation. However, along the extreme easterly edge of the basin magnesium is the most prevalent cation, indicating the influence of inflow from Santa Rosa Basin and of water emanating from volcanic rocks which bound the basin on the east. Ground waters derived from the alluvium are usually of poor quality with total dissolved solids in concentrations generally in excess of 2,000 ppm and boron concentrations generally greater than 0.5 ppm. There are, however, isolated instances where waters of excellent quality are derived from the alluvial deposits.

Calleguas-Conejo Hydrologic Unit. Mineral quality of ground water in Simi Basin varies both areally and according to the geologic formation from which the water is drawn. Water pumped from the alluvium contains total dissolved solids varying from about 600 to 2,100 ppm, with boron concentrations ranging from 0.0 to 2.7 ppm. Effective salinities range from about 5 to 18 epm. Ground water in the eastern end of the basin is generally of better quality than ground water found in the western end. Water pumped from the Tertiary and Cretaceous formations varies from excellent mineral quality, with low concentrations of salts and boron, to marginal quality. Ground water derived from the Santa Barbara formation in Tapo Canyon within the Simi Hydrologic Subunit is low in dissolved salts and boron, and generally is of good quality for

irrigation or domestic uses.

Ground waters in East and West Las Posas Basins are extracted from four principal aquifers, namely, Recent and Pleistocene alluvium, the Epworth gravels and Fox Canyon aquifer of the San Pedro formation, and the Grimes Canyon aquifer of the Santa Barbara formation. In general, ground water derived from the principal aquifers in the East and West Las Posas Basins contains concentrations of dissolved solids varying from about 200 ppm to 4,900 ppm, with boron concentrations ranging from 0.0 ppm to 2.4 ppm. Effective salinities vary from about 1.0 epm to in excess of 50 epm. Ground water found in the alluvium contains high concentrations of dissolved solids and boron and generally is considered unsatisfactory for irrigation and domestic use. Ground water found in the Fox Canyon aquifer is generally of excellent mineral quality with low boron concentrations and effective salinities. Ground water extracted from the Epworth gravels appears to be of excellent mineral quality. Analyses of ground water extracted from the Grimes Canyon aquifer indicate waters of class 1 to class 2 quality for irrigation use with effective salinities ranging from about 5.5 to over 8.5 epm.

Ground water in Conejo Basin obtained from the alluvium is generally marginal in quality, having dissolved solids ranging from about 1,200 ppm to 2,000 ppm. Wells drawing from volcanic rocks in this basin yield ground water with dissolved solids from about 350 ppm to about 1,100 ppm, averaging less than 650 ppm, and with generally low boron concentrations. This water is considered of good quality for both irrigation and domestic uses. Ground water obtained from the Miocene formations ranges from class 1 to class 3 for irrigation use, with total dissolved solids ranging from about 400 to 2,060 ppm and averaging 1,350 ppm. The

boron content is low, with the maximum concentration for all available analyses being 0.2 ppm.

Ground water in Tierra Rejada Basin is considered suitable for prevailing beneficial uses, with total dissolved solids generally less than 600 ppm and boron concentrations ranging from 0.0 to 0.4 ppm. Effective salinities are generally less than 5 epm.

Ground water in Santa Rosa Basin varies in mineral quality in accordance with the location and formation from which it is extracted. In general, all formations presently utilized yield ground water suitable for prevailing beneficial uses. Dissolved solids are generally less than 700 ppm, with boron concentrations varying from 0.1 ppm to 0.6 ppm. Effective salinities range from about 3.5 epm to 8 epm.

TABLE 19

## SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY

BASIN AND WELL NUMBER	DATE SAMPLED	CONDUCTANCE, (EC x 10 <sup>6</sup> ) AT 250C	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										: TOTAL	: DISSOLVED SOLIDS, IN PPM	: EFFECTIVE SALINITY, IN EPM	: PER CENT SODIUM
			CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>	FLUORIDE, IN PPM				
VENTURA HYDROLOGIC UNIT																
UPPER OJAI 4N/22W-10K2	8-4-52 <sup>B</sup>	883	4.78	1.72	3.04	0.01	0	6.22	1.90	1.46	0.04	0.5	0.1	612	3.3	32
OJAI 4N/22W-5L1	5-17-33 <sup>C</sup>	---	4.34	1.89	1.09	---	-	3.68	3.16	0.54	---	---	Tr.	---	3.0	15
	8-1-52 <sup>B</sup>	788	5.23	1.97	1.39	0.03	0	4.09	3.52	0.69	0.26	0.3	0.1	513	3.4	16
UPPER VENTURA RIVER 3N/23W-5H1	5-18-33 <sup>C</sup>	---	7.43	3.21	2.66	---	-	5.06	6.70	1.52	---	---	0.5	---	5.9	20
	8-1-52 <sup>B</sup>	966	6.55	2.32	1.88	0.06	0	4.61	5.10	1.12	0.14	0.3	0.3	612	4.4	18
SANTA CLARA RIVER HYDROLOGIC UNIT																
PIRU 4N/18W-19P1	11-25-24 <sup>C</sup>	---	6.48	3.04	6.78	---	-	4.54	10.88	0.87	---	---	---	---	9.8	42
	1-9-52 <sup>D</sup>	1570	8.23	5.76	5.04	0.10	0	4.98	12.68	1.16	0.13	0.7	1.0	1190	10.9	26
FILLMORE 3N/20W-6N1	10-1-29 <sup>C</sup>	1080	6.53	2.88	3.52	---	-	4.94	7.20	0.79	---	---	0.4	---	6.4	27
	9-8-45 <sup>E</sup>	---	6.90	3.63	3.43	0.02	0	4.54	7.87	1.21	0.09	---	0.6	962	6.8	25
4N/20W-23L1	8-26-52	685	3.75	1.55	1.82	0.04	0	4.32	1.41	0.90	0.34	1.0	0.1	443	2.8	26
SANTA PAULA 3N/21W-11E2	5-1-29 <sup>F</sup>	---	6.63	2.64	3.00	---	0	5.44	5.64	1.18	---	---	0.3	879 <sup>6</sup>	5.6	24



SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY<sup>1</sup>

BASIN AND WELL NUMBER	DATE SAMPLED	CONDUCTANCE: (EC X 10 <sup>6</sup> AT 25°C)	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL		
			CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>	FLUORIDE, IN PPM	BORON, IN PPM	DISSOLVED SOLIDS, IN PPM	EFFECTIVE SALINITY, IN PPM
MOUND 2N/22W-17N2	4-4-31C	1610	8.37	4.20	5.52	---	-	5.51	10.35	2.32	---	---	0.5	---	9.7 30
	9-5-52	---	7.25	3.37	5.30	0.13	0	5.24	9.02	2.03	0.05	0.7	0.2	1060	8.8 34
	8-1-52BH	1710	9.35	4.17	6.68	0.14	0	6.21	9.38	4.53	0.11	0.3	0.4	1354	11.0 33
OXNARD FOREBAY 2N/22W-17A2	10-13-27C	---	7.68	3.70	5.30	---	---	5.29	10.30	1.58	---	---	---	---	9.0 32
	7-15-52B	1655	8.08	4.48	6.87	0.14	0	5.96	11.42	1.75	0.19	0.3	0.6	1251	11.5 35
	4-3-31F	1240	6.33	3.62	4.39	---	-	4.65	8.36	1.30	---	---	0.6	1004E	8.0 31
OXNARD PLAIN 1N/22W-18E1 (OXNARD)	9-30-52F	---	6.45	3.36	3.78	---	-	4.24	8.32	1.18	---	0.9	0.7	958E	7.1 28
	2-21-34E	---	6.40	3.28	5.39	---	-	4.20	8.84	2.03	---	---	0.6	1044	8.6 36
	6-6-52B	1131	6.17	3.24	4.13	---	0	4.20	8.04	1.06	0.08	1.3	0.4	940	7.4 30
PLEASANT VALLEY 2N/21W-25K2 (FOX CANYON)	5-18-46E	---	13.95	6.47	8.70	---	0	4.30	18.66	5.81	0.15	---	0.7	1926	15.2 30

TABLE 19 (CONTINUED)

## SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY

BASIN AND WELL NUMBER	DATE SAMPLED	CONDUCTANCE, (EC x 10 <sup>6</sup> ) AT 25°C	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL	FLUORIDE, IN PPM	BORON, IN PPM	DISSOLVED SOLIDS, IN PPM	EFFECTIVE SALINITY, IN PPM	PER CENT SODIUM IN EPH
			Ca	Mg	Na + K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	Cl	NO <sub>3</sub>								
PLEASANT VALLEY 2N/21W-25K2 (FOX CANYON)	3-30-48E	---	6.20	2.62	3.78	---	0	3.97	5.69	2.31	0.44	---	0.3	867	6.4	30		
	6-24-52 <sup>B</sup>	1890	7.94	4.94	8.57	0.15	0	5.19	11.60	4.73	0.05	0.1	0.2	1492	13.7	40		
1N/21W-11R1 (ALLUVIUM)	6-25-52 <sup>B</sup>	3160	13.59	10.56	12.38	---	0	6.76	18.12	11.51	0	0.2	0.8	2452	22.9	34		
	7-22-52 <sup>B</sup>	1605	5.21	7.15	6.36	0.05	0	8.65	5.48	3.90	0.58	0.0	0.1	1097	10.1	34		
CALLEGUAS-CONEJO HYDROLOGIC UNIT																		
2N/18W 8F6 (ALLUVIUM)	10-19-51 <sup>B</sup>	1920	13.00	8.40	9.14	---	-	5.28	20.70	4.43	0.03	0.8	1.2	2078	17.5	30		
	10-18-51 <sup>B</sup>	1275	6.08	2.92	3.17	---	-	5.13	5.08	2.14	0.08	---	Tr.	757	6.1	26		
2N/18W-18F1 (TERTIARY FORMATION)	7-29-52 <sup>B</sup>	644	2.72	2.28	1.82	0.04	0	4.68	0.87	1.26	0.08	0.5	0.1	340	2.2	27		
	7-21-52 <sup>B</sup>	2700	17.47	7.43	8.43	0.12	0	6.72	19.80	4.91	1.89	0.1	0.2	2286	15.0	26		
EAST AND WEST LAS POSAS																		
2N/19W-7C1 (ALLUVIUM)																		

SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY<sup>A</sup>

A ANALYSIS BY DIVISION OF WATER RESOURCES, UNLESS OTHERWISE NOTED.  
B ANALYSIS BY PACIFIC CHEMICAL CONSULTANTS.  
C ANALYSIS FROM BULLETIN 46A. DIVISION OF WATER RESOURCES.  
D ANALYSIS BY UNITED STATES GEOLOGICAL SURVEY, WATER QUALITY BRANCH; UNPUBLISHED RECORDS SUBJECT TO REVISION.  
E ANALYSIS BY FRUIT GROWERS LABORATORY, INC.  
F ANALYSIS OBTAINED FROM SANTA CLARA WATER CONSERVATION DISTRICT.  
G TOTAL DISSOLVED SOLIDS REPORTED AS A SUM OF THE CONSTITUENTS.  
H WELL CEMENTED ABOVE 300 FEET (DATE UNCERTAIN).

TABLE 20

SELECTED MINERAL ANALYSES OF DRAINAGE WATERS FROM  
SEMI-PERCHED ZONE IN VICINITY OF PORT HUENEME

NUMBER OF SAMPLING POINT	NUMBER ON PLATE 22	DATE SAMPLED	CONDUCTANCE: (EC x 10 <sup>6</sup> ) AT 25°C	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL		
				CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>	BORON, IN PPM	DISSOLVED SOLIDS, IN PPM	EFFECTIVE SALINITY, IN PPM	PER CENT SODIUM
1N/22W-7J	1	6-4-52 <sup>B</sup>	4220	20.50	17.83	18.10	---	0	5.75	47.18	3.95	0.52	1.6	3503	35.9	32
1N/22W-7J	2	1-14-53	3774	18.5	15.3	15.2	0.17	0	6.64	39.1	4.09	0.37	2.5	3628	30.7	31
1N/22W-18A	3	1-14-53	3774	18.3	14.0	16.5	0.15	0	5.44	36.4	6.65	0.25	1.9	3428	20.6	34
1N/22W-18B	4	8-4-52 <sup>B</sup>	5780	18.62	22.41	35.60	0.18	0	6.72	58.90	9.60	0.46	3.6	5131	58.2	46
1N/22W-21B	5	8-4-52 <sup>B</sup>	1830	12.44	5.87	5.90	0.12	0	5.36	16.30	2.07	0.34	0.9	1674	11.9	25
1N/22W-21F	6	6-6-52 <sup>B</sup>	2150	13.55	5.37	7.03	---	0	5.41	17.61	2.40	0.30	0.8	1846	12.4	27
1N/22W-21F	7	1-14-53	2198	13.9	6.00	7.17	0.13	0	5.48	18.6	2.48	0.22	1.0	1832	13.3	27
1N/22W-21Q	8	8-4-52 <sup>B</sup>	2218	13.08	5.65	7.04	0.13	0	5.48	17.63	2.66	0.20	0.9	1760	12.8	28
1N/22W-27C	9	6-6-52 <sup>B</sup>	4110	14.00	16.60	20.62	---	0	5.45	40.20	5.74	0.80	1.8	3500	37.2	40
1N/22W-27C	10	8-4-52	2994	16.0	12.2	16.1	0.10	0	5.28	32.8	5.08	0.91	1.9	3010	28.4	36
1N/22W-27C	11	1-14-53	4149	15.3	15.4	27.0	0.20	0	5.52	44.8	6.96	0.94	2.7	3565	42.6	47

<sup>A</sup> ANALYSIS BY DIVISION OF WATER RESOURCES UNLESS OTHERWISE NOTED.

<sup>B</sup> ANALYSIS BY PACIFIC CHEMICAL CONSULTANTS.



## Sources of Impairment

Sources of impairment to the quality of waters of Ventura County include natural sources, domestic sewage, irrigation return water, industrial wastes, and sea-water intrusion. There is presented herein after a brief discussion of each of these sources as related to its cause and character. Although not actually a source of impairment to ground water quality in themselves, improperly constructed, defective, and abandoned wells may be a factor in transmission of pollution, contamination, or degradation to usable ground waters, through the introduction of surface or drainage waters or the leachings from cesspools and septic tanks. Such wells may allow the interchange of waters between aquifers having differing quality characteristics, thus degrading good quality waters.

Natural Sources. The mineral quality of water is adversely affected by natural causes in several portions of Ventura County. In general, this natural degradation is a minor source of impairment to the quality of surface and ground waters. Sespe and Piru Creeks receive small flows of water with high boron concentration originating from abandoned mining operations. In addition, Piru Creek water is degraded by boron originating in colemanite deposits in Lockwood Valley. It is believed that the relatively high concentrations of boron noted in ground water of Piru Basin are primarily the result of percolation of the degraded Piru Creek water in the basin. In the vicinity of South Mountain and the Topatopa Mountains, natural seeps of connate brines reportedly occur, containing high concentrations of dissolved salts. These brines drain into Santa Paula Creek, the Santa Clara River, and Ojai Valley. It is reported

that there are three springs on Upper Matilija Creek from which emanate waters of high boron content, which adversely affect the quality of low flows of Matilija Creek.

Domestic Sewage. Domestic sewage returning to ground water through cesspools, septic tanks, and leach lines, or from community treatment plants, is of higher mineral content than the source water. Investigations have shown increases of 20 to 50 ppm in chlorides, 30 to 60 ppm in sodium, and 15 to 25 ppm in nitrogen\* some of which may oxidize to  $\text{NO}_3$ . These increases in mineral content are so small, however, that domestic sewage in the Santa Clara River Valley, Upper Ventura River Valley, and Ojai Valley may be considered as a satisfactory source of ground water replenishment, and from this standpoint susceptible of treatment and conservation. However, as was mentioned heretofore, most waters in Ventura County are considered to be very hard. Concentrated salt wastes resulting from the regeneration of individually owned softening units could render the quality of sewage unsuitable for reuse, and cause localized pollution problems. Similar problems could be created by imprudent discharge by central regeneration plants.

Irrigation Return Water. Irrigation of agricultural crops requires an application of water in excess of the consumptive requirement for water to prevent undue build-up of salts in the root zone. This excess water, or irrigation return water, may contain from two to as many as ten times the concentration of salts found in the original water supply. In the Oxnard Plain and Mound Basins, where the pumped aquifers are confined, subsurface and open drains have been constructed to remove

\*Values are from paper, "The Mineral Pickup Resulting from the Utilization of Water for Domestic Purposes", given at American Geophysical Union by Ralph Stone, February, 1952.

the irrigation return and rainfall percolate. Analyses show these drainage waters to contain from 1,800 to over 5,000 ppm of total dissolved solids. In areas where irrigation return water can percolate to the ground water, it may constitute an important source of degradation to the water supply.

Industrial Wastes. The development of natural resources and the growth of industry, including agriculture, in Ventura County have created a multitude of waste disposal problems. Whenever harmful liquid or water soluble industrial wastes are discharged into stream channels, onto the ground, or into unlined sumps, they constitute a threat of pollution to underlying ground water.

Sources of industrial wastes in Ventura County include the oil industry, citrus and walnut packing plants, refuse disposal sites, slaughter houses, and hog farms. Wastes derived from the oil industry include connate brines of high salt content pumped from the oil sands, and "contaminated" drilling muds. Wastes from citrus packing houses may include any one, or a combination of borax, soda ash, sodium hypo-chlorite, and/or soap, depending upon the individual plant operation. Wastes from walnut packing houses usually contain high concentrations of sodium chloride. Refuse disposed of in dumps will on decomposition release salts, which when dissolved by rainfall or applied water may percolate to ground water. Wastes from slaughter houses and garbage on hog farms is usually of an organic nature, which if not suitably treated or handled may produce septicity in water supplies, with accompanying foul odors.

Sea-Water Intrusion. In the Oxnard Plain Basin, it was noted that mineral analyses of water from certain wells in the vicinity of Port Hueneme during the recent drought period evidenced higher concentrations of chlorides and dissolved solids than did other water from the



Oxnard aquifer. In Table 21 there are presented complete mineral analyses of waters from wells so affected. A thorough study of this portion of the aquifer reduced the probable sources of chloride degradation in the ground water to one or more of the following:

1. Sea water intrusion through the Oxnard aquifer.
2. Percolation, or leakage through poorly constructed wells, defective casings, or abandoned wells of:
  - a. Irrigation return water and other poor quality waters from the semi-perched ground water body.
  - b. Sea water which had intruded into the semi-perched ground water body.

A method of differentiating between ground water degraded by sea-water and by semi-perched ground water is by comparison of the character of the two waters with that of the degraded ground water. This may be conveniently done employing a geochemical chart, by use of which the chemical character of waters can be graphically depicted.

If two waters of different character are mixed, it is logical to presume that the character of the resulting mixture will be a combination of the characters of the two waters. Thus, if the character of waters from sources of degradation are plotted on a geochemical chart, together with the character of the degraded water, the source of degradation may become apparent. Plate 22, entitled "Mineral Character of Ground Water in Vicinity of Port Hueneme and Point Mugu", shows on geochemical chart "A" the anion constituents, expressed in per cent, in the degraded water and in the two apparent sources of degradation. Also plotted on this chart are anion constituents in ground water from these wells prior to degradation. Inspection of Plate 22 will show that the indicated source of degradation of water from wells in the vicinity of Port Hueneme was sea water. The character of the anion constituents in the degraded ground water plots almost in a direct line between the character of

undegraded ground water and sea water. There was no apparent influence of the ground water found in the semi-perched body on the character of the degraded ground water. Anion constituents only were used in this chart, since cation constituents are subject to character changing influences such as cation exchange.

In an effort to distinguish between possible methods by which sea water entered the Oxnard aquifer, consideration was given to the hydrologic and geologic conditions that existed in the area of intrusion. As described previously, the Oxnard aquifer appears to outcrop in the submarine canyon near Port Hueneme. Furthermore, the semi-perched zone appears to extend under the coastal sand dunes to the ocean. Thus, from the geologic standpoint, sea water might enter either of these two water-bearing zones. Before sea water could intrude, however, a condition would have to exist whereby the hydraulic head of the sea water was greater than that prevailing in the respective aquifers. Concerning this possibility in the semi-perched zone, information obtained from studies of the Division of Irrigation and Soils of the University of California at Los Angeles was of significance. This agency determined elevations of the perched water table throughout the Oxnard Plain Basin, as a part of its study of drainage problems. These elevations indicated that throughout the basin the perched water surface sloped toward the ocean and exceeded mean sea level, thus precluding the possibility of sea water intrusion thereto.

Subsequent to 1949 with the prevailing trough in the piezometric levels in the Oxnard aquifer, conditions were conducive to the intrusion of sea water. A correlation between elevations of the piezometric surface in Oxnard aquifer and increase in chloride concentration in the ground in

the Oxnard aquifer and saline intrusion is indicated on Plate 23, entitled "Elevation of Ground Water and Chloride Ion Concentration". On this plate there is plotted the hydrograph of well number 1N/22W-20R1, together with the average weekly chloride ion concentration in water from well number 1N/22W-29A2, both of which are perforated in the Oxnard aquifer. An inspection of Plate 23, will show that during the period when the water surface elevation in well number 1N/22W-20R1 was lowest, the rate of increase in chloride concentration in the ground water was the greatest, once degradation had started. As an example, during the period from September 1st until about the 13th of December, 1951, the elevation of the water surface in well number 1N/22W-20R1 slowly increased from about minus 14 feet to about minus 2 feet, and the rate of increase in chloride concentration in water from well number 1N/22W-29A2 averaged 3.9 ppm per day. In the subsequent period, December 13, 1951 to March 15, 1952, water surface elevations averaged slightly above sea level, and the rate of increase in chloride concentration in the water was reduced to about 1.5 ppm per day. Although it appears anomalous that the chloride concentration should have increased while water surface elevations in the key well slightly exceeded sea level, consideration should be given to the fact that the top of the Oxnard aquifer in this vicinity is between 80 to 120 feet below sea level, and that the specific gravity of sea water exceeds that of fresh water. In view of this, a water surface elevation in the Oxnard aquifer of more than two feet is required in order to maintain equilibrium with the sea water. Furthermore, prior to May, 1952, the prevailing piezometric level in parts of the central portion of the basin was below sea level, so that an overall landward gradient was maintained.

In view of the lack of required hydraulic slope for intrusion



through the semi-perched zone, together with the observed correlation between water surface elevations in the Oxnard aquifer and the increase in chlorides, it appears that sea water has entered directly into the Oxnard aquifer.

The determined extent of saline intrusion in Oxnard Plain Basin has been limited to an area in the immediate vicinity of Port Hueneme, as shown on Plate 16-B, and has been apparent only in wells numbers 1N/22W-20N1, 1N/22W-20R1, 1N/22W-29A2, and 1N/22W-29C1.

Ground water in well number 1N/21W-28D1, which was perforated in the Oxnard aquifer, and was reported in Division of Water Resources Bulletin No. 46 to have been degraded by the intrusion of sea water, recovered its former quality with increase in piezometric levels above sea level and recession of sea water from the aquifer. This improvement in quality is depicted on geochemical chart B on Plate 22.

TABLE 21

SELECTED MINERAL ANALYSES OF WATERS FROM SALINE INTRUDED WELLS A  
IN VICINITY OF PORT HUENEME

POINT NUMBER:	DATE	CONDUCTANCE:	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL	BORON, DISSOLVED:	EFFECTIVE:	PER CENT
WELL NUMBER :	ON PLATE 22 :	(EC x 10 <sup>6</sup> ) :	CA :	MG :	NA :	K :	CO <sub>3</sub> :	HCO <sub>3</sub> :	SO <sub>4</sub> :	CL :	NO <sub>3</sub> :	IN PPM :	SOLIDS, :	SALINITY, :	SODIUM	
:	:	AT 25°C) :	:	:	:	:	:	:	:	:	:	IN PPM :	IN PPM :	IN PPM :	IN PPM :	
N 1	4- 3-31	1180	5.94	2.55	4.56	---	---	4.05	7.87	1.21	---	---	0.63	923	7.1	35
N 2	9- 4-31	---	6.09	3.54	3.82	---	---	4.13	8.05	1.27	---	---	---	936	7.4	28
N 3	6- 3-32	---	6.24	3.30	4.05	---	---	4.10	8.23	1.21	---	---	0.68	946	7.4	30
N 4	3- 3-33	---	5.99	3.38	4.00	---	---	4.08	8.10	1.16	---	---	0.60	932	7.4	30
N 5	7-21-36	---	6.89	3.95	4.35	0.31	---	4.06	8.50	2.90	---	---	---	1057	8.6	30
N 6	12-20-39	---	6.24	3.38	3.82	---	---	3.80	8.22	1.38	---	---	0.50	930	7.2	28
N 7	9-27-45	---	6.14	3.30	3.87	---	0.47	3.75	7.85	1.22	---	---	0.63	915	7.2	29
N 8	4-30-48	---	6.84	3.46	4.60	0.38	---	3.80	8.33	2.99	---	---	---	1048	8.4	33
N 9	7-16-48	---	7.83	4.28	7.52	---	---	3.90	8.31	7.25	---	---	---	1286	11.8	38

TABLE 21 (CONTINUED)

SELECTED MINERAL ANALYSES OF WATERS FROM SALINE INTRUDED WELLS<sup>A</sup>  
IN VICINITY OF PORT HUENEME

WELL NUMBER	POINT NUMBER	DATE SAMPLED	CONDUCTANCE, (EC X 10 <sup>6</sup> ) AT 25(C)	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL			BORON, DISSOLVED	EFFECTIVE PER CENT
				CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>		IN PPM	SOLIDS, IN PPM	SALINITY, IN PPM	SODIUM	
1N/22W-20N1	N 10	10- 7-49	----	100.95	58.39	127.31	----	--	3.34	28.42	252.36	----	----	----	16176	254.9	44	
	N 11	10- 8-49	----	91.22	50.00	126.31	----	--	3.41	26.57	236.29	----	----	----	15204	237.6	47	
	N 12	3-23-50	----	50.15	12.42	60.87	0.66	--	3.49	1.42	119.14	----	----	----	7088	119.2	50	
1N/22W-20R1	- --	9- 2-52 <sup>B</sup>	5465	20.7	12.2	23.0	0.24	0	3.96	10.8	42.6	0.01	0.70	0.9	4070	41.4	41	
	- --	12- 2-52 <sup>B</sup>	7770	25.18	14.37	44.40	0.37	0	4.03	13.90	65.90	0.07	0.9	0.92	5675	66.4	53	
1N/22W-28D1	D 1	6- 5-31 <sup>D</sup>	8120	20.86	15.08	49.50	----	--	5.39	18.32	61.75	----	----	----	----	64.6	58	
	D 2	6- 9-31 <sup>D</sup>	6560	17.20	10.70	38.70	----	--	3.10	15.68	47.90	----	1.12	1.12	----	49.4	58	
	D 3	6-26-31 <sup>DE</sup>	8350	20.44	15.48	53.80	----	--	5.60	20.20	64.00	----	1.48	1.48	----	69.3	60	
	D 4	6-26-31 <sup>DF</sup>	8150	19.75	15.16	50.35	----	--	5.65	17.72	62.00	----	1.47	1.47	----	65.5	59	
	D 5	6- 3-32 <sup>D</sup>	----	6.09	3.62	4.70	----	--	3.83	8.50	2.03	----	0.71	0.71	----	8.3	33	
	D 6	3- 3-33 <sup>D</sup>	----	6.04	3.38	4.25	----	--	4.22	8.25	1.19	----	0.63	0.63	----	7.6	31	



TABLE 21 (CONTINUED)

SELECTED MINERAL ANALYSES OF WATERS FROM SALINE INTRUDED WELLS  
IN VICINITY OF PORT HUENEME

WELL NUMBER	POINT NUMBER	DATE SAMPLED	CONDUCTANCE: (EC X 10 <sup>6</sup> : AT 25°C)	MINERAL CONSTITUENTS, IN EQUIVALENTS PER MILLION										TOTAL			BORON, DISSOLVED: EFFECTIVE: PER CENT		
				CA	MG	NA	K	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	CL	NO <sub>3</sub>		IN PPM	SOLIDS, IN PPM	SALINITY, IN EPM			
1W/22N-29A2	A 1	3-31-47	---	6.20	3.38	3.87	0.18	--	4.15	8.23	1.19	0.03		0.52	954	7.4		28	
	A 2	5-5-49	---	6.20	3.28	4.13	0.10	--	4.08	8.44	1.16	0.03		---	960	7.4		30	
	A 3	5-25-51	---	6.45	3.77	3.56	0.37	--	4.08	8.46	1.58	0.03		---	985	7.7		25	
	A 4	7-25-51	---	6.90	3.85	3.95	---	--	4.05	8.04	2.48	0.03		---	999	7.8		27	
	A 5	9-4-51	---	7.80	4.27	4.22	0.06	0	4.01	8.19	4.12	0.03		---	1092	8.6		26	
	A 6	11-27-51	---	12.10	6.31	5.04	---	0	3.69	8.21	11.34	0.01		---	1457	11.6		22	
	A 7	3-28-52	---	15.45	3.36	5.52	---	0	3.65	9.02	16.47	0		---	1780	11.7		23	
	A 8	6-6-52 <sup>B</sup>	3086	20.5	11.7	5.65	0.18	0	3.84	7.60	26.6	0.02		0.51	3200	26.6		15	
1W/22N-29C1	--	9-2-52 <sup>B</sup>	3817	21.2	11.4	7.18	0.22	0	3.20	6.78	30.2	0		0.48	3020	30.1		18	

A ANALYSIS OBTAINED FROM SANTA CLARA WATER CONSERVATION DISTRICT, UNLESS OTHERWISE NOTED.

B ANALYSIS BY DIVISION OF WATER RESOURCES.

C ANALYSIS BY PACIFIC CHEMICAL CONSULTANTS.

D ANALYSIS FROM BULLETIN 46-A. DIVISION OF WATER RESOURCES.

E SAMPLED AT LOW TIDE.

F SAMPLED AT HIGH TIDE.

### Safe Yield of Presently Developed Water Supply

An evaluation of the safe yield of existing sources of water supply in Ventura County under present conditions of development and utilization is presented in this section. As has been stated previously, surface storage developments and uncontrolled stream flow comprise only secondary sources of water supply in the County, while water stored in ground water basins presently constitutes the primary source of supply.

The term "safe yield", when used in this bulletin in connection with a surface storage development, refers to the maximum sustained rate of draft from the reservoir that could have been maintained throughout a critically deficient water supply period. When used in connection with a diversion from the unregulated flow of a surface stream, the term similarly refers to the maximum sustained rate of diversion from the stream that could have been maintained throughout a critically deficient water supply period. Water supplies as they occurred during the base period from 1936-37 through 1950-51 were utilized in determining safe yield of surface reservoirs and surface stream diversions in Ventura County. In most cases the dry seasons from 1944-45 through 1950-51 constituted the critically deficient water supply portion of this period. In general, estimates of safe yield are presented in this bulletin in terms of seasonal rate of yield.

The term "net safe yield" refers to that portion of the safe yield resulting from a proposed new water supply development and method of operation thereof that would have been wasted without the proposed works and under the present pattern of land and water utilization, and is used synonymously with the term "new water".

When used in reference to water supplies available from ground water storage, the term "safe yield" refers to the maximum rate of net extraction from the ground water basin which, if continued over an indefinitely long period of years, would result in the maintenance of certain desirable fixed conditions.

Commonly, safe ground water yield is determined by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water basin does not exceed mean seasonal replenishment to the basin.

2. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of degradants or pollutants.

3. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping from the ground water basin or by exclusion of the users from a supply therefrom.

In the determination of the safe yield of ground water basins of Ventura County, it was found that each of these criteria applied to one or more of the basins.

Commonly, safe yield of a ground water basin is not determined until there is evidence of overdraft or use of water in excess of safe yield. Many of the basins in Ventura County are now experiencing such overdraft. On the other hand, others are not being utilized to the maximum extent possible under limitations imposed by the foregoing criteria. With increased use of these presently underdeveloped basins, ground water levels would be further lowered during drought periods, thereby providing additional space in the basins for storage of percolating surface waters that would otherwise waste to the ocean during wet periods. The effect thereof would be an increase in yield of the basins. Furthermore, in certain basins where overdraft now prevails, it appears that safe yield could be increased through modification of the present pumping patterns.

Since safe ground water yield is not a fixed value but is a function of pumping patterns and the magnitude of ground water basin utilization, together with other factors, further definition of the term is considered necessary. As used in this bulletin, therefore, the term "safe ground water yield" refers to the maximum rate of net extraction of ground water that could be maintained over



### Safe Yield of Presently Developed Water Supply

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The term "net safe yield" refers to that portion of the safe yield resulting from a proposed new water supply development and method of operation thereof that would have been wasted without the proposed works and under the present pattern of land and water utilization, and is used synonymously with the term "new water".

When used in reference to water supplies available from ground water storage, the term "safe yield" refers to the maximum rate of net extraction from the ground water basin which, if continued over an indefinitely long period of years, would result in the maintenance of certain desirable fixed conditions.

Upper Ojai Subunit. The source of water supply for the Upper Ojai Subunit is ground water in Upper Ojai Basin. Since it appears that natural replenishment is satisfying the present relatively minor water requirements of the water users, the safe yield of this basin was taken as equal to the estimated average seasonal net extraction of water therefrom during the base period, or about 400 acre-feet per season. It is believed that this amount represents about the maximum rate of extraction that could be maintained from the basin.

Ojai Subunit. Since water requirements of the Ojai Subunit for both lands overlying the ground water basin and lands overlying adjacent nonwater-bearing formations are supplied by pumping from Ojai Basin, the safe yield of the water supply of the subunit was taken as equal to that estimated for the ground water basin. As stated previously, from the spring of 1944 to the fall of 1951, net retention of tributary surface runoff and of direct precipitation in Ojai Basin totaled an estimated 43,000 acre-feet. Of this amount, it was estimated that consumptive use of direct precipitation, and consumptive use of ground water by phreatophytes amounted to about 42,800 acre-feet, leaving only a negligible amount to meet extractions of water from the basin for beneficial use. However, an estimated 10,900 acre-feet of water stored in the ground water basin in the spring of 1944 could have been extracted without violating the third of the criteria governing safe ground water yield. Thus, the safe yield of Ojai Basin was estimated as the summation of the two items of supply, amounting to about 11,100 acre-feet, divided by the number of seasons in the period of analysis, or about 1,500 acre-feet per season.

Upper and Lower Ventura River Subunits. Stream flow originating in Matilija and the North Fork of Matilija Creeks, ground water in Upper Ventura River Basin and in Mound Basin underlying Lower Ventura River Basin, and ground water in low-yielding sediments east and west of the Ventura River above Foster Park comprise the sources of water supply of the Upper and Lower Ventura River

Subunits. Since 1948, runoff in Matilija Creek has been regulated by Matilija Reservoir.

It was estimated that during the drought period, if Matilija Reservoir had not been in operation, about 4,900 acre-feet per season would have been available to meet requirements of ground water users in Upper Ventura Basin and of diverters of surface flow between the confluence of Matilija and the North Fork of Matilija Creeks to and including the diversion of the City of Ventura at Foster Park. This supply was taken as the safe seasonal yield of these water sources. Of the estimated 4,900 acre-foot safe seasonal yield, it was determined that about 3,900 acre-feet would have been available for pumpage or diversion by the City, and that about 1,000 acre-feet would have been available for surface and ground water users above Foster Park.

Had Matilija Dam been in operation during the drought period, it was estimated that the reservoir would have last filled in the spring of 1947, and that with an average seasonal draft of 3,700 acre-feet during the ensuing four and one-half year period the reservoir would have been empty by the fall of 1951. It was further estimated that about 2,300 acre-feet of the average seasonal draft from the reservoir would have been put to beneficial use by users above Foster Park, including the City of Ventura, even if the reservoir had not been in operation. Thus, the net safe yield developed by Matilija Reservoir would have averaged about 1,400 acre-feet per season.

It is known that during the drought period many wells drawing from the minor ground water sources in the Upper Ventura River Subunit, and supplying lands east and west of the Ventura River above Foster Park, went dry. The average requirement for consumptive use of applied water on these lands was estimated to have been about 800 acre-feet per season. Safe yield of the minor ground water sources was estimated to have been equal to about 60 per cent of this requirement, or about 500 acre-feet per season. This estimate was based on the assumption that



these sources yielded no more water in proportion to the requirement of land served therefrom than did other ground water sources in Upper Ventura River Basin and surface flow in the Ventura River.

The portion of the safe yield of Mound Basin available to meet water requirements in the Ventura Hydrologic Unit was taken as equal to the average seasonal extraction of ground water therefrom during the base period by users in the Lower Ventura River Subunit west of the Ventura River, or an estimated 600 acre-feet per season. This amount includes an estimated 100 acre-feet of water per season extracted in this area and exported for use in the Rincon Subunit. The extraction of ground water from Mound Basin by the City of Ventura from 1947-48 through 1950-51 was considered to have been but a temporary expedient, and it was assumed that this source would not be available indefinitely to the City. This assumption was based on the fact that a pumping depression, with its center considerably below sea level, formed in the piezometric surface of the aquifer in Mound Basin when the city wells were operating. Thus, conditions were conducive to the intrusion of sea water into the pumped aquifer. It is probable that the principal source of replenishment to the aquifer is percolation of direct precipitation and of surface flow in minor watercourses in the outcrop area of the San Pedro formation north of the City, which supplies appear to be inadequate to satisfy the pumping demands on this portion of the aquifer.

Rincon Subunit. In addition to the aforementioned import from the Lower Ventura River Subunit, some water in the Rincon Subunit is obtained by pumping from small ground water basins at the mouths of several minor streams discharging to the ocean along the coastal front. The safe yield of these minor ground water basins was estimated to be about 100 acre-feet per season, which amount was taken as the safe yield of the Rincon Subunit. It is known that many wells in the subunit were dry during the latter years of the drought period. This fact, together with the prevailing poor quality of certain of the ground waters, necessitated trucked importation of drinking water for many users.

## Santa Clara River Hydrologic Unit

Since water requirements of the Santa Clara River Hydrologic Unit are largely met by pumping from ground water storage, the safe yield of presently developed water supplies therein was taken as the safe yield of the ground water basins, estimated to be about 72,200 acre-feet per season. This estimate, however, includes the relatively minor yield of surface waters diverted and utilized in the hydrologic unit. No differentiation was made between yield of surface and ground water sources, since it is probable that diverted surface water would otherwise percolate and be retained in the ground water basins. Furthermore, it was assumed that in the free ground water areas the unconsumed residuum of surface waters applied to urban and irrigated lands would return to ground water storage and be available for re-use.

The total safe water supply available to meet requirements in the Santa Clara River Hydrologic Unit was estimated to be about 73,200 acre-feet per season. This supply is comprised of the foregoing safe yield of about 72,200 acre-feet per season, less an export from the Oxnard Forebay Subunit to the West Las Posas Subunit of the Calleguas-Conejo Hydrologic Unit averaging about 1,100 acre-feet per season, plus average seasonal imports of Santa Clara River water from Los Angeles County to the Eastern and Piru Subunits totaling about 2,100 acre-feet.

Table 23 summarizes the estimated safe seasonal yield of the presently developed water supply in the Santa Clara River Hydrologic Unit. The values shown for the Eastern and Piru Subunits do not include the aforementioned imports from Los Angeles County. The total value for the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits does include the cited export to the Calleguas-Conejo Hydrologic Unit.

TABLE 23

ESTIMATED SAFE SEASONAL YIELD OF PRESENTLY DEVELOPED  
WATER SUPPLY IN SANTA CLARA RIVER HYDROLOGIC UNIT

Subunit	: Acre-feet
Eastern	0
Piru	11,100
Fillmore	10,000
Santa Paula	15,600
Mound	8,800
Oxnard Forebay, Oxnard Plain, and Pleasant Valley	<u>26,700</u>
TOTAL	72,200

Eastern Subunit. Water supplies for developed lands in the Eastern Subunit, so far as could be determined, are obtained entirely by importation of Santa Clara River water from Los Angeles County in the estimated average amount of about 300 acre-feet per season.

Piru, Fillmore, and Santa Paula Subunits. Derivation of the safe seasonal ground water yields of Piru, Fillmore, and Santa Paula Basins, which, as stated previously, were taken as the yields of the water supplies of the respective subunits, is shown in Table 24. The values in the table for items tending to increase and decrease yields of the basins are estimated average seasonal quantities over the base period. Derivation of values for consumptive use of precipitation was based on analyses discussed in Chapter III, and the values given include consumptive use of ground water by phreatophytes. The estimate of safe yield of Piru Basin does not include an average seasonal import of about 1,800 acre-feet of water from Los Angeles County.



TABLE 24

ESTIMATED SAFE SEASONAL YIELD OF PIRU,  
FILLMORE, AND SANTA PAULA GROUND WATER BASINS

(In acre-feet)

Item	:	Basin		
	:	Piru	Fillmore	Santa Paula
<u>Items tending to increase yield</u>				
Surface inflow	102,000	176,900	209,700	
Subsurface inflow	0	20,600	11,500	
Precipitation on basin	<u>9,600</u>	<u>25,800</u>	<u>18,500</u>	
Subtotals to be added	111,600	223,300	239,700	
<u>Items tending to decrease yield</u>				
Surface outflow	72,900	181,300	203,200	
Subsurface outflow	20,600	11,500	7,200	
Consumptive use of precipitation	<u>7,000</u>	<u>20,500</u>	<u>13,700</u>	
Subtotals to be subtracted	100,500	213,300	224,100	
SAFE YIELD	<u>11,100</u>	<u>10,000</u>	<u>15,600</u>	

It should be noted that the derived "safe yields" shown in Table 24 are not the maximum yields which could be developed in these basins. As stated in an earlier section, utility of the Piru, Fillmore, and Santa Paula Basins is limited largely by factors of economic pumping lift and mean seasonal recharge, and not by storage capacity or configuration of the basins. Therefore, it appears that their yields could be increased to the limit of mean seasonal recharge if not prohibited by economic considerations. Achievement of such increases, however, would require greater utilization of the basins than with present patterns of land use and water supply development, and greater ranges in pumping lifts, and might result in the creation of adverse salt balances in the basins.

It should be further noted in Table 24 that the safe yield indicated for a given basin is not necessarily the amount of water that is available for use in that basin. In Piru Basin, of the indicated safe yield of about 11,100

acre-feet per season, some 5,700 acre-feet per season represents an export to Fillmore Basin. The estimated safe water supply available to meet requirements in Piru Basin is comprised of the indicated safe yield less this export, plus the aforementioned import from Los Angeles County in the amount of about 1,800 acre-feet per season, or a total of about 7,200 acre-feet per season. In Fillmore Basin, of the indicated safe yield of about 10,000 acre-feet per season, approximately 1,400 acre-feet per season is exported to Santa Paula Basin. Therefore, the estimated safe water supply available to meet requirements in Fillmore Basin is comprised of the indicated safe yield less the export, plus the import from Piru Basin, or a total of about 14,300 acre-feet per season. Of the indicated safe yield in Santa Paula Basin of some 15,600 acre-feet per season, about 600 acre-feet per season is exported to Mound Basin and about 700 acre-feet to Oxnard Plain Basin. The estimated safe water supply available to meet requirements in Santa Paula Basin, therefore, is comprised of the indicated safe yield less the exports, plus the import from Fillmore Basin, or a total of approximately 15,700 acre-feet per season.

Mound Subunit. Safe yield of the Mound Subunit was taken as equal to that portion of the average seasonal extraction of ground water from Mound Basin that was utilized within the Mound Subunit during the base period, or an estimated 8,800 acre-feet per season. This estimate does not include extractions of water from Mound Basin by the City of Ventura nor by users west of the Ventura River.

Since independent evaluation of the amount of recharge to Mound Basin during the drought period could not be made with data at hand, it is possible that experience will show that the foregoing estimate of safe yield is excessive. In this connection, it appears that in the westerly portion of the basin near the ocean, where ground water levels were below sea level subsequent to 1947, a portion of the extracted ground water was obtained from aquifers in the seaward extension of the San Pedro formation. Furthermore, the observed depression in the

piezometric surface in this area indicates that transmissibility of the aquifers was inadequate to meet the pumping demands by underflow from Santa Paula Basin, the probable principal source of recharge. It is also possible that a portion of the supply to the aquifers may have come from perennial change in ground water storage in the outcrop areas of the San Pedro formation. Any of these occurrences would tend to decrease the estimated safe ground water yield of the subunit.

The estimated safe water supply available to meet requirements in the Mound Subunit is composed of the safe ground water yield of about 8,800 acre-feet per season, plus imports from Santa Paula and Oxnard Forebay Subunits of about 2,700 acre-feet per season, or a total of approximately 11,500 acre-feet per season.

Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits. The sources of water supply for these subunits are Santa Clara River water and direct precipitation that percolate in Oxnard Forebay Basin, subsurface inflow to Oxnard Forebay Basin from Santa Paula Basin, and subsurface inflow from the Calleguas-Conejo Hydrologic Unit to Oxnard Plain and Pleasant Valley Basins. In addition, water is imported to Oxnard Plain Basin from Santa Paula Basin. The total safe yield of these supplies, other than the import from Santa Paula Basin, was estimated to be about 26,700 acre-feet per season.

It has been stated that troughs formed in the piezometric surfaces in the Oxnard aquifer in Oxnard Plain Basin and in the Fox Canyon aquifer in Pleasant Valley Basin during the drought period, thus creating conditions conducive to sea-water intrusion. Furthermore, the mineral characteristics of ground water extracted from the Oxnard aquifer in the vicinity of Port Hueneme indicated that sea water had actually advanced inland to a portion of the aquifer then being pumped. Therefore, the second of the three criteria listed previously for determination of safe ground water yield was violated.



The occurrence of a trough in the piezometric surface of a confined aquifer is a function of the rate of pumping from the aquifer, the transmissibility of the aquifer, and the hydraulic head available in the forebay supplying the aquifer. With data available, it was not possible to determine independently the transmissibility of either the Oxnard or Fox Canyon aquifers. Since transmissibility is a function of the cross-sectional area and permeability of an aquifer, which factors are probably subject to little variance in a confined aquifer, it was assumed that transmissibility in the Oxnard and Fox Canyon aquifers would remain constant under various piezometric slopes and rates of pumping draft. Relationships between water level elevations in Oxnard Forebay Basin, rates of pumping draft from the Oxnard aquifer, and slopes in the piezometric surface in the Oxnard aquifer were established. Using these relationships it was determined that, with the present pattern and rate of pumping from the Oxnard aquifer, the ground water level at well number 2N/22W-23H3 in Oxnard Forebay Basin must be maintained at or above 60 feet above sea level in order to maintain a seaward gradient in the piezometric surface in the Oxnard aquifer, and to prevent formation of a trough therein. This would limit ground water storage depletion in Oxnard Forebay Basin to about 20,000 acre-feet, as compared to the actual storage depletion of about 109,500 acre-feet which prevailed in the fall of 1951.

Analyses were made for the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins to determine the maximum average seasonal ground water extractions that could have been made therefrom over the base period without causing formation of a trough in the piezometric surface in the Oxnard aquifer and thereby creating conditions conducive to sea-water intrusion. It was assumed that Oxnard Forebay Basin would have been full at the beginning of the drought period, and that supplies available for extraction would have been ground water in storage in the basin, together with surface and subsurface inflow retained therein, plus subsurface inflow to Pleasant Valley and Oxnard Plain Basins from the

Calleguas-Conejo Hydrologic Unit. Consideration was not given to the item of "undifferentiated supply from other sources" shown in Table 15. By a trial and error method involving monthly analyses of water supply and disposal, it was determined that a maximum of about 26,700 acre-feet of water per season could have been extracted from the three basins throughout the drought period. With this reduced pumpage, ground water storage in Oxnard Forebay Basin would have been depleted by about 87,000 acre-feet, and a seaward gradient would have been maintained in the piezometric surface in the Oxnard aquifer throughout the drought period. It was assumed, furthermore, that under these conditions a trough would not have formed in the piezometric surface in the Fox Canyon aquifer. Total safe yield of the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins, therefore, was estimated to be about 26,700 acre-feet per season, and was assumed to be equal to total safe yield of the corresponding subunits. Of this amount, about 4,700 acre-feet per season represents subsurface inflow from the Calleguas-Conejo Hydrologic Unit, and the remainder is comprised of supply from the Santa Clara River system.

It should be noted that possible subsurface outflow to the ocean through the Fox Canyon aquifer could not be evaluated, and was not considered in the foregoing analysis. The amount of such outflow would reduce the estimate of safe yield accordingly.

An item of water supply which would appear to increase the estimate of safe yield of the three subunits is that portion of the aforementioned "undifferentiated supply from other sources" which is comprised of inflow from fresh water stored in seaward extensions of the Oxnard and Fox Canyon aquifers. However, for purposes of the present studies this supply was not considered to be safe yield. Although the volume of this storage may be of considerable magnitude, and extractions therefrom during drought periods may be replaced by subsurface flow from Oxnard Forebay Basin during wet periods, utility of the storage appears to be

limited by the two canyons incised in the ocean floor near Port Hueneme and Point Mugu. Experience during the recent drought period showed that utilization of the storage resulted in the intrusion of sea water from Hueneme Canyon to a portion of the Oxnard aquifer then being pumped.

That portion of the "undifferentiated supply from other sources" possibly contributed to the Oxnard and Fox Canyon aquifers by percolation of direct rainfall and of the unconsumed portion of applied water would correspondingly increase the estimated safe yield. Since the magnitude of this possible supply could not be determined with data available, and since there are even uncertainties regarding its actual occurrence, it was not given consideration in the evaluation of safe yield of the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins.

Table 25 summarizes the derivation of safe yield of the three basins. The values given are average seasonal values for the drought period from 1944-45 through 1950-51. The value for consumptive use of precipitation in Oxnard Forebay Basin was based on analyses described in Chapter III, and includes consumptive use of water by phreatophytes. The item for subsurface outflow includes only that in the Oxnard aquifer, and as mentioned does not include possible outflow in the Fox Canyon aquifer. The indicated total safe yield of 26,700 acre-feet per season includes about 4,100 acre-feet per season exported to the Mound Subunit and to the Calleguas-Conejo Hydrologic Unit.



TABLE 25

ESTIMATED SAFE SEASONAL YIELD OF OXNARD FOREBAY,  
OXNARD PLAIN, AND PLEASANT VALLEY BASINS

Item	: Acre-feet
<u>Items tending to increase yield</u>	
Surface inflow	48,300
Subsurface inflow	
From Santa Paula Basin	7,200
From Calleguas-Conejo Hydrologic Unit	4,700
Precipitation on Oxnard Forebay Basin	5,300
Ground water storage depletion in Oxnard Forebay Basin	12,700
	<hr/>
Subtotal to be added	78,200
<u>Items tending to decrease yield</u>	
Surface outflow	28,800
Subsurface outflow	15,900
Consumptive use of precipitation in Oxnard Forebay Basin	6,800
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Subtotal to be subtracted	51,500
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SAFE YIELD	26,700

If extractions of water from Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins were limited to the estimated safe yield of 26,700 acre-feet per season, and ground water storage depletion in Oxnard Forebay Basin was limited to 87,000 acre-feet, there would be increases in surface outflow in the Santa Clara River to the ocean and in subsurface outflow through the Oxnard aquifer. This increased outflow would result from maintenance of higher ground water levels in Oxnard Forebay Basin. Such higher levels would decrease ground water storage capacity available for storing percolating waters of the Santa Clara River, thereby increasing surface outflow, and would also increase the slope of the piezometric surface in the Oxnard aquifer to the ocean, thereby increasing the rate of subsurface outflow. Table 26 presents a comparison of estimated outflow from the Santa Clara River Hydrologic Unit during the base period and under present operating

conditions, with such outflow if the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins had been operated in accordance with their estimated safe yield of 26,700 acre-feet per season. The comparison does not consider possible subsurface outflow in the Fox Canyon aquifer.

TABLE 26

ESTIMATED SEASONAL OUTFLOW FROM SANTA CLARA RIVER  
HYDROLOGIC UNIT DURING BASE PERIOD, WITH PRESENT  
METHOD OF OPERATION, AND WITH OXNARD FOREBAY,  
OXNARD PLAIN, AND PLEASANT VALLEY BASINS  
OPERATED IN ACCORDANCE WITH THEIR SAFE YIELD

(In acre-feet)

Season	Surface outflow			Subsurface outflow*		
	Present	Safe yield	Increase	Present	Safe yield	Increase
	: operation	: operation		: operation	: operation	
1936-37	160,200	160,200	0	12,000	12,000	0
1937-38	435,600	464,700	29,100	21,600	21,600	0
1938-39	53,600	66,100	12,500	23,600	23,600	0
1939-40	27,000	27,000	0	23,100	23,100	0
1940-41	687,600	802,400	114,800	23,500	23,500	0
1941-42	70,800	87,400	16,600	23,800	23,800	0
1942-43	379,000	430,700	51,700	23,400	23,400	0
1943-44	299,500	353,400	53,900	23,500	23,500	0
1944-45	69,900	77,600	7,700	23,500	23,500	0
1945-46	59,300	70,600	11,300	9,200	23,400	14,200
1946-47	43,900	53,500	9,600	8,800	23,500	14,700
1947-48	0	0	0	3,600	20,200	16,600
1948-49	0	0	0	1,000	12,000	11,000
1949-50	0	0	0	0	6,600	6,600
1950-51	0	0	0	0	2,100	2,100
Average for base period, 1936-37 through 1950-51	152,400	172,900	20,500	14,700	19,100	4,300
Average for wet period, 1936-37 through 1943-44	264,200	299,000	34,800	21,800	21,800	0
Average for drought period, 1944-45 through 1950-51	24,700	28,800	4,100	6,600	15,900	9,300

\* From Oxnard aquifer only.

It should be mentioned that of the estimated 26,700 acre-foot safe seasonal yield of the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, it was assumed that about 2,500 acre-feet would be exported for use in the Mound Subunit, and about 1,600 acre-feet for use in the West Las Posas Subunit of the Calleguas-Conejo Hydrologic Unit, which practices actually prevailed during the drought period. It was further assumed that some 500 acre-feet per season would be imported from Santa Paula Basin during a drought period for use in the Oxnard Plain Subunit. Thus, the safe water supply available to meet requirements in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits during a drought period would be the estimated safe ground water yield therein, less the exports to the Mound Subunit and the Calleguas-Conejo Hydrologic Unit, plus the import from Santa Paula Basin, or about 23,100 acre-feet per season. It was estimated that during a mean period of water supply and climate the exports and imports would change to about 3,200 and 700 acre-feet per season, respectively, and that the safe water supply available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits would increase to about 24,200 acre-feet per season.

#### Calleguas-Conejo Hydrologic Unit

Since ground water is the primary source of water supply in the Calleguas-Conejo Hydrologic Unit, safe ground water yield therein was taken as equal to safe yield of the unit. As described previously in this chapter, Simi, East and West Las Posas, and Tierra Rejada Basins are experiencing perennial lowering of ground water levels, indicating a violation of the first of the three cited criteria governing determination of safe ground water yield. It is possible, also, that this perennial lowering is resulting in a condition of adverse salt balance, thereby violating the second of the criteria. Furthermore, in Conejo and Tierra Rejada Basins, prevailing low-yielding water-bearing formations and irregularities in the fracture systems in the volcanic rocks have precluded extensive utilization of ground water storage, and it appears that these basins are presently being utilized



to about the maximum practicable extent. Based on these considerations, safe ground water yield in the Calleguas-Conejo Hydrologic Unit was taken as equal to the average seasonal ground water replenishment during the base period, estimated to have been about 22,600 acre-feet.

Table 27 presents the estimated safe ground water yield of each of the subunits in the Calleguas-Conejo Hydrologic Unit. The value shown for the East and West Las Posas Subunits does not include some 1,100 acre-feet of water per season imported from Oxnard Plain Basin.

TABLE 27

ESTIMATED SAFE SEASONAL YIELD OF PRESENTLY  
DEVELOPED WATER SUPPLY IN  
CALLEGUAS-CONEJO HYDROLOGIC UNIT

Subunit	: Acre-feet
Simi	6,100
East and West Las Posas	10,800
Conejo	2,600
Tierra Rejada	500
Santa Rosa	<u>2,600</u>
TOTAL	22,600

Simi Subunit. The derivation of the estimate of safe seasonal yield of Simi Basin is shown in Table 28. The values shown are average seasonal quantities over the base period from 1936-37 through 1950-51. The item for surface inflow does not include an average quantity of about 1,400 acre-feet of water per season imported from Tapo Canyon, a small ground water basin northeast of Simi Basin. The item for consumptive use of precipitation was based on the results of analyses described in Chapter III, and includes consumptive use of ground water by phreato-phytes.

TABLE 28  
ESTIMATED SAFE SEASONAL YIELD  
OF SIMI GROUND WATER BASIN

Item	: Acre-feet
<u>Items tending to increase yield</u>	
Surface inflow	3,900
Direct precipitation on ground water basin	13,300
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Subtotal to be added	17,200
<u>Items tending to decrease yield</u>	
Surface outflow	1,100
Subsurface outflow	100
Consumptive use of precipitation	<u>11,300</u>
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Subtotal to be subtracted	12,500
	<hr/>
SAFE YIELD	4,700

In addition to the estimated 4,700 acre-foot safe yield of Simi Basin, importation of ground water from Tapo Canyon averaged about 1,400 acre-feet per season during the base period. It was assumed that this amount represents the safe yield of this minor basin. Thus, the safe water supply available to meet requirements in the Simi Subunit was estimated to total about 6,100 acre-feet per season.

East and West Las Posas Subunits. The average seasonal ground water replenishment of East and West Las Posas Basins during the base period, which replenishment was taken as equal to the safe yield therein, was evaluated as a differential in solution of the equation of hydrologic equilibrium. Seasonal consumptive use of applied water was estimated to have averaged about 16,900 acre-feet. Importation of water from Oxnard Plain Basin in the average amount of approximately 1,100 acre-feet per season served to meet a portion of this consumptive use. The average seasonal decrement in ground water storage, which also served to meet a

portion of the consumptive use, was estimated to have been about 5,000 acre-feet. By subtracting the sum of the estimated seasonal decrement in ground water storage and seasonal importation from the estimated seasonal consumptive use of applied water, net ground water replenishment was estimated to have averaged about 10,800 acre-feet per season. The safe water supply available to meet requirements in the East and West Las Posas Subunits was estimated to be approximately 11,900 acre-feet per season, comprised of the foregoing safe ground water yield of about 10,800 acre-feet per season, plus the importation from Oxnard Plain Basin of some 1,100 acre-feet per season.

Conejo Subunit. Since available data were insufficient to permit quantitative evaluation of the items of water supply and disposal in the Conejo Subunit during the base period, and since it appears that water requirements of the present water service area therein are being satisfied by natural replenishment of the Conejo ground water basin, safe yield of the subunit was taken as equal to the estimated average seasonal net extraction of ground water during the base period, or about 2,600 acre-feet per season.

Tierra Rejada Subunit. A few ground water level measurements available in Tierra Rejada Basin since 1930 indicate that disposal of ground water from the basin has probably exceeded replenishment thereof. It was estimated that beneficial use of ground water extracted from the basin during the base period averaged about 1,000 acre-feet per season, of which some 500 acre-feet represented consumptive use of applied water within the subunit, and the remaining 500 acre-feet represented an exportation to the Santa Rosa Subunit. Replenishment of Tierra Rejada Basin is largely from percolation of the unconsumed portion of direct precipitation. Since precipitation averages less than 14 inches of depth per season over the 4,390 acres in the subunit, it is believed that the average seasonal net replenishment of the basin could be no more than about 500 acre-feet. This amount was taken as the safe seasonal yield of the Tierra Rejada Subunit.



Santa Rosa Subunit. For reasons cited in the case of the Conejo Subunit,

safe yield of the Santa Rosa Subunit was taken as equal to the average seasonal net extraction of ground water therein during the base period, estimated to have been about 2,600 acre-feet. The safe water supply available to meet requirements in the Santa Rosa Subunit is comprised of this safe ground water yield plus the importation from Tierra Rejada Subunit in the amount of about 500 acre-feet per season, or a total of approximately 3,100 acre-feet per season.

Malibu Hydrologic Unit

The present water service area in the Malibu Hydrologic Unit, comprising less than 500 acres of irrigated and suburban lands, obtains its water supply by pumping ground water occurring primarily in fractured volcanic rocks. The water-using developments are largely in Hidden and Russell Valleys. Since it appears that present water requirements are being satisfied by natural replenishment, safe ground water yield in the Malibu Hydrologic Unit was taken as equal to the average seasonal consumptive use of applied water therein during the base period, estimated to have been about 800 acre-feet.



### CHAPTER III. WATER UTILIZATION AND REQUIREMENTS

The nature and magnitude of water utilization and requirements in Ventura County, both at the present time and under probable ultimate conditions of development, are considered in this chapter. In connection with the discussion, the following terms are used as defined:

Water Utilization--This term is used in a broad sense to include all employments of water by nature or man, whether consumptive or non-consumptive, as well as irrecoverable losses of water incidental to such employment, and is synonymous with the term "water use".

Demands for Water--Those factors pertaining to specific rates, times, and places of delivery of water, losses of water, quality of water, etc., imposed by the control, development, and use of the water for beneficial purposes.

Water Requirement--The amount of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. As utilized in this bulletin, the term refers only to consumptive uses of applied water and attendant irrecoverable losses.

Supplemental Water Requirement--The water requirement over and above the sum of safe ground water yield and safe surface water yield.

Consumptive Use of Water--This refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of land use.

Applied Water--The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. It does not include direct precipitation.

Effective Precipitation--This refers to that portion of direct precipitation which is consumptively used and which does not run off or percolate to ground water.



Irrigation Efficiency--This refers to the ratio of consumptive use of applied water to the total amount of applied water, and is commonly expressed as a percentage.

Ultimate--This refers to conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized. (It is realized that any present forecasts of the nature and extent of such ultimate development, and resultant water utilization, are inherently subject to possible large errors in detail and appreciable error in the aggregate. However, such forecasts, when based upon best available data and present judgment, are of value in establishing long-range objectives for development of water resources. They are so used herein, with full knowledge that their re-evaluation after the experience of a period of years may result in considerable revision.)

Present water requirements in Ventura County were determined by application of appropriate unit use of water factors to the present pattern of land use, from estimates of ground water extractions, and from estimated and measured diversions from surface streams to agricultural and urban entities. Probable ultimate water requirements were estimated from consideration of the probable ultimate pattern of land use and appropriate unit use of water factors. In determining the present and probable ultimate water requirements of Ventura County, due consideration was given to those natural features of the County, such as topography, geology, and soils, as they affect the use and re-use of water. As indicated by the foregoing definition, supplemental water requirements were estimated as the differences between derived values of safe yield and water requirements under present and probable ultimate conditions of development.

Certain possible non-consumptive requirements for water in Ventura County, such as those for hydroelectric power generation, flood control,

conservation of fish and wildlife, recreation, etc., may be of varying significance in the final design of works to meet supplemental consumptive requirements for water in the County. In most instances, the magnitudes of such non-consumptive requirements are relatively indeterminate, and dependent upon allocations made in design after consideration of factors of economics. For these reasons, water requirements for hydroelectric power generation, flood control, conservation of fish and wildlife, and recreation were considered to be outside the scope of the present investigation and are not evaluated in this bulletin.

Water utilization and requirements are considered and evaluated in this chapter under the general headings: "Present Water Supply Development", "Land Use", "Unit Use of Water", "Water Requirements", "Demands for Water", and "Supplemental Water Requirements".

#### Present Water Supply Development

As stated previously, the seasonal and cyclic vagaries of stream flow in Ventura County have precluded the dependency on unregulated surface water as a firm source of water supply. The resulting extensive utilization of ground water storage has enabled the County to achieve its present stage of development. With the exception of Matilija Dam and Reservoir, constructed in 1948 by the Ventura County Flood Control District on Matilija Creek, a tributary of the Ventura River, and of a few relatively minor additional surface storage developments, the entire regulation of the natural water supply of Ventura County is obtained from ground water storage.

Irrigated and urban lands are primarily served by pumped wells drawing from underlying ground water basins. The results of a County-wide canvass of wells conducted during the investigation indicated that there were in excess of 1,350 wells of heavy draft, equipped with pumps having motors of five

horsepower or greater, supplying water to meet irrigation requirements within the County. There were also in excess of 150 wells of heavy draft supplying water for urban and suburban uses. The irrigation wells are generally individually owned, although there are many mutual water companies in the County that obtain their water from a single well or a series of wells and distribute the water on a share basis.

In 1951, there were 92 mutual water companies in Ventura County, serving water for domestic and irrigation purposes to shareholders and members. Approximately 23,000 acres of irrigated land and more than 5,000 service connections in various portions of the County were served with water by these mutual water companies. At the same time there were four municipally owned public utilities supplying water to approximately 11,100 service connections, and seven county water districts with about 2,000 service connections. In addition, there were nine privately owned utilities supplying both domestic and irrigation water to in excess of 5,000 service connections.

Utilization of surface water in Ventura County is limited to a relatively few users along the Ventura and Santa Clara Rivers and their tributaries. Along the Santa Clara River, these users divert either the uncontrolled surface flow of Piru, Sespe, and Santa Paula Creeks or the effluent discharge from ground water storage at the lower limits of Eastern, Piru, Fillmore, and Santa Paula Basins. Since water supplies from these sources are not dependable in quantity, and in some years are accustomed to diminish completely, many lands supplied therefrom are also equipped to pump supplemental water from ground water storage.

On the Ventura River, the City of Ventura is the largest user of surface water. The City has constructed a submerged concrete diversion weir to bedrock, almost completely across the Ventura River channel immediately downstream from the mouth of Coyote Creek near Foster Park. When available, Ventura



River is diverted by gravity into the city system. When necessary, the City of Ventura also pumps ground water in Upper Ventura River Basin from a well field located a short distance upstream from the diversion weir. In 1947, when water supplies from these sources became insufficient to meet its requirements, the City pumped supplemental water from a well drilled in Mound Basin near the beach in the southeasterly portion of the City. Subsequently in 1948, three additional wells were constructed in this vicinity and were utilized until the wet season 1951-52.

Upstream from the City's Foster Park diversion weir, there are several gravity diversions supplying water to agricultural and minor urban entities adjacent to the river. Mr. Harold Conkling, Consulting Engineer, in his report entitled "Safe Yield - Matilija Reservoir", May, 1948, estimated that about 500 acres of land above Meiners Oaks were so served. During wet periods, there are some minor surface diversions effected below the Foster Park weir. Table 29 lists the major diversions of surface water in Ventura County, their sources of water supply, the general location of lands served, the points of diversion, the estimated present average seasonal diversions, and the principal use of the diverted supplies.

TABLE 29

## MAJOR DIVERSIONS OF SURFACE WATER IN VENTURA COUNTY

User	Source of supply	General location of lands served	Point of diversion	Estimated present average seasonal diversion, in acre-feet	Principal use
Miscellaneous users above Meiners Oaks <sup>a</sup>	Ventura River	Upper Ventura River Subunit	Between confluence of Matilija and North Fork of Matilija Creeks and Meiners Oaks	1,100	Irrigation
City of Ventura	Ventura River	City of Ventura	At Foster Park	5,700 <sup>b</sup>	Municipal
Waring Bros. Irrigation Service	Piru Creek	Piru Subunit	$\frac{1}{2}$ mile above railroad bridge at town of Piru	800	Irrigation
United Water Conservation District (Piru Spreading Grounds)	Piru Creek	Piru Subunit	At town of Piru	See Table 31	Ground water replenishment
Fillmore Irrigation Company	Sespe Creek	Fillmore Subunit	1 mile above U.S.G.S. gaging station near Fillmore	4,600	Irrigation
Farmer's Irrigation Company	Santa Clara River	Santa Paula and Mound Subunits	1 mile above Santa Paula bridge	1,300	Irrigation
Miscellaneous agricultural users above Santa Paula Water works diversion	Santa Paula Creek	Santa Paula Subunit	-----	300	Irrigation
Santa Paula Water Works, Ltd.	Santa Paula Creek	City of Santa Paula	At U.S.G.S. gaging station near Santa Paula	2,800	Municipal
Santa Clara Water and Irrigation Company	Santa Clara River	Oxnard Plain Subunit	Near town of Saticoy	700	Irrigation
United Water Conservation District (Saticoy Spreading Grounds)	Santa Clara River	Oxnard Forebay Subunit	Near town of Saticoy	See Table 31	Ground water replenishment

<sup>a</sup>From report "Safe Yield - Matilija Reservoir", May, 1948, by Harold Conkling, Consulting Engineer.<sup>b</sup>Estimated present water requirement of City of Ventura. City would divert this amount if available.

Matilija Dam is a concrete arch structure with an overpour spillway, 163 feet in height above stream bed, creating a reservoir with storage capacity of about 7,000 acre-feet. The dry seasons that followed the completion of Matilija Dam in 1948 rendered the reservoir virtually ineffective in providing water to meet the then current water supply deficiencies in the Ventura Hydrologic Unit. It was not until January, 1952, that Matilija Reservoir first filled and spilled. During 1952, about 3,200 acre-feet of water from the reservoir were delivered through a pipe line with a 12-inch terminal diameter and spread on grounds constructed by the Ventura County Flood Control District in Ojai Basin. In addition, about 3,700 acre-feet of the stored water were released in that year directly down the Ventura River, for diversion by the City of Ventura and other users and for replenishment of Upper Ventura River Basin. A minor amount of water from Matilija Reservoir was delivered directly to users in Ojai Basin for irrigation purposes.

In addition to Matilija Dam, there are nine other impounding structures in Ventura County which, because of their height or reservoir storage capacity, are considered "dams" under the provisions of the State Water Code pertaining to safety of dams. By definition in the code, any such structure across a natural drainage channel that is greater than 25 feet in height or capable of storing more than 50 acre-feet of water is considered a dam, excepting that such structures that are less than six feet in height regardless of storage capacity, and structures that are not capable of storing 15 acre-feet of water regardless of height, are not considered dams and are exempt from State jurisdiction. Table 30 presents a list of eight of the dams in Ventura County which were within the jurisdiction of the State of California as of 1953, and which were utilized for stream flow regulation, together with pertinent information for each. Two other dams in the County, under jurisdiction of the State of California but not listed in Table 30, are utilized to impound wastes from oil field operations.



TABLE 30

## DAMS AND RESERVOIRS IN VENTURA COUNTY

Name	Owner	Stream	Type	Height of dam : from stream : bed to crest, : in feet :	Reservoir : area, in : acres :	Storage : capacity, : in acre-feet :	Drainage : area, in : square : miles :	Date constructed :	Purpose
Round Mountain	Carmello State Hospital	Long Canyon Creek	Earthfill	10	---	92	.16	1927	Flood control
Matilija	Ventura County Flood Control District	Matilija Creek	Concrete arch	163	124.0	7,000	55	1949*	Municipal and irrigation
Runkle	Ventura County Flood Control District	Tributary of Arroyo Simi	Earthfill	40	7.1	100	1.57	1949	Ground water replenishment and soil con- servation
Dennison	Dennison Ranch Company	Lion Canyon Creek	Concrete slab and buttress	32	---	60	6.8	1929	Irrigation
Anola	Otto G. Wilhelm	Tributary of Santa Ana Creek	Earthfill	38	2.0	30	.05	1924	Irrigation
Lake Sherwood	Lake Sherwood Country Club	Triunfo Creek	Constant radius con- crete arch	43	184.0	2,694	16.0	1904	Recreation
Lake Eleanor	Southern Counties Land Company	Eleanor Creek	Constant radius con- crete arch	37	9.0	104	1.2	1881	Recreation
El Rancho Cola	Elizabeth Winthrop Allison	Coyote Creek	Earthfill	53	17.2	335	15.0	1951	Irrigation and domestic water supply

\* Storage began March 14, 1948.

Artificial regulation of surface waters of the Santa Clara River system is provided by their diversion to and percolation in the Piru and Saticoy spreading grounds, constructed by the Santa Clara Water Conservation District and now operated by the United Water Conservation District. Excess flows are diverted from Piru Creek to the Piru spreading grounds, located immediately south of the town of Piru, through an unlined ditch having a capacity of about 75 second-feet. Water is diverted from the Santa Clara River to the Saticoy spreading grounds, located about one mile southeast of the town of Saticoy on the southeast side of the river, through an unlined ditch with a capacity of about 145 second-feet. During the wet season of 1951-52, about 11,800 acre-feet of water were diverted and percolated in the Piru spreading grounds. During the same season, about 25,400 acre-feet were similarly percolated in the Saticoy spreading grounds. As mentioned previously, spreading grounds were formerly operated by the Santa Clara Water Conservation District near the City of Santa Paula, wherein surface flow in Santa Paula Creek was spread. Operation of the Santa Paula spreading grounds was abandoned subsequent to the season of 1940-41 because of prevailing high ground water levels in Santa Paula Basin. Measured seasonal diversions to the three spreading grounds during the base period are shown in Table 31.

TABLE 31

MEASURED DIVERSIONS OF SURFACE FLOW TO SPREADING GROUNDS  
IN SANTA CLARA RIVER HYDROLOGIC UNIT, DURING BASE PERIOD

(In acre-feet)

Season	: Piru : spreading : grounds	: Saticoy : spreading : grounds	: Santa Paula : spreading : grounds	: Totals
1936-37	8,194	20,137	3,121	31,452
1937-38	6,664	13,652	750	21,066
1938-39	6,768	13,545	1,889	22,202
1939-40	5,103	16,790	900	22,793
1940-41	5,672	396	1,306	7,374
1941-42	0	0	0	0
1942-43	3,226	0	0	3,226
1943-44	0	1,956	0	1,956
1944-45	8,912	4,738	0	13,650
1945-46	7,067	17,243	0	24,310
1946-47	10,045	22,758	0	32,803
1947-48	1,318	7,804	0	9,122
1948-49	1,840	5,530	0	7,370
1949-50	3,780	9,700	0	13,480
1950-51	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
TOTALS	68,589	134,249	7,966	210,804

Land Use

As a first step in estimating the water requirements of Ventura County, survey determinations were made of the nature and extent of present land use as related to water utilization. Similarly, the probable nature and extent of ultimate land use were forecast on the basis of land classification and habitable area survey data, which segregated lands of the County in accordance with their suitability for irrigated agriculture and possible development to urban and suburban types of land use.



## Past and Present Patterns of Land Use

In connection with the preparation of State Water Resources Board Bulletin No. 2, a detailed land use survey was conducted throughout the southerly developed portion of Ventura County during the season of 1949-50. During 1950-51, a resurvey was made in connection with the present investigation to ascertain changes in land use subsequent to the original survey. It was determined that such changes were minor. The 1949-50 survey, therefore, was adopted as representative of present conditions of development in Ventura County.

In the 1949-50 survey, the entire area shown on Plate 3, entitled "Hydrologic Units" was field mapped, and from the resulting maps the areal extent of each class and type of land use, including both those requiring water service and native vegetation and other types not requiring water service, was determined. A determination was also made of the areal extent of each class and type of land use overlying the major ground water basins. In agricultural areas, results of the survey were reduced by the estimated percentages of non-productive land, such as county and state highways, farm access roads, and lots; and the net irrigated area of each crop was estimated. Similarly, the gross areas of various types of urban development were determined and were then reduced by appropriate percentages of streets and walks, etc., to obtain the net water-using area. Table 32 summarizes, by hydrologic unit and subunit, the nature and extent of lands in Ventura County presently requiring water service. The areal extent of urban and irrigated lands in Ventura County during 1949-50 is delineated on Plates 24-A, 24-B, and 24-C, entitled "Present and Probable Ultimate Land Use". Table 33 presents a summary of present land use in the four hydrologic units, indicating the location of various classes of land use with respect to the major ground water basins.

TABLE 32

## PRESENT WATER SERVICE AREAS IN VENTURA COUNTY

(In acres)

Class and type of land use	Ventura Hydrologic Unit					
	Upper Ojai : Subunit	Ojai : Subunit	Upper Ventura : River Subunit	Lower Ventura : River Subunit	Rincon : Subunit	Subtotals
<b>Urban and Suburban Lands</b>						
Residential, single	20	231	321	722	38	1,332
Residential, multiple	0	10	11	51	10	82
Residential, estate	0	122	28	28	9	187
Residential, rural	8	48	266	13	13	348
Commercial	0	31	21	197	12	261
Industrial, manufacturing	22	6	2	327	0	357
Schools	2	40	17	71	0	130
Dairies	0	1	8	10	0	19
Livestock and poultry ranches	1	0	2	36	3	49
Net urban and suburban area	53	489	683	1,455	85	2,765
Military reservations*	0	0	0	0	0	0
Industrial, extractive	53	0	0	1,692	844	2,589
Subdivided, not occupied	0	174	16	0	0	190
Airports	0	0	14	0	0	14
Vacant	0	176	135	285	0	596
Streets and roads	18	178	206	909	77	1,388
Gross urban and suburban area	124	1,017	1,054	4,341	1,006	7,542
<b>Irrigated Lands</b>						
Alfalfa	0	14	208	2	0	224
Pasture	0	134	39	143	9	325
Nuts	146	107	229	103	0	585
Deciduous	10	30	46	53	0	139
Citrus	9	1,412	438	556	119	2,534
Truck	0	19	81	44	1	145
Beans	0	0	23	11	0	34
Hay and grain	0	0	0	0	0	0
Nursery	0	0	13	1	0	14
Net irrigated area	165	1,716	1,077	914	129	4,000
Streets and roads	2	79	50	52	6	196
Gross irrigated area	174	1,795	1,127	965	135	4,196
GROSS AREA REQUIRING WATER SERVICE	298	2,812	2,181	5,306	1,141	11,738

TABLE 32 (Continued)

## PRESENT WATER SERVICE AREAS IN VENTURA COUNTY

(In acres)

Class and type of land use	Santa Clara River Hydrologic Unit									
	Eastern	Piru	Fillmore	Santa Paula	Mound	Oxnard	Forebay	Oxnard	Pleasant	Subtotals
	: Subunit	: Subunit	: Subunit	: Subunit	: Subunit	: Subunit	: Subunit	: Subunit	: Subunit	
<b>Urban and suburban lands</b>										
Residential, single	0	70	203	538	160	43		800	144	1,958
Residential, multiple	0	0	38	63	18	10		94	70	293
Residential, estate	0	12	23	60	20	2		70	30	217
Residential, rural	0	14	14	62	41	88		220	102	541
Commercial	0	8	34	67	17	24		177	20	347
Industrial, manufacturing	0	8	70	82	22	46		127	20	375
Schools	0	3	21	47	19	15		35	13	153
Dairies	0	0	0	9	0	6		18	50	83
Livestock and poultry ranches	0	23	77	47	11	11		100	110	379
Net urban and suburban area	0	138	480	975	308	245		1,641	559	4,346
Military reservations*	0	0	0	0	0	0		4,937	0	4,937
Industrial, extractive	0	1,428	1,009	813	91	0		15	0	3,356
Subdivided, not occupied	0	2	11	18	0	10		28	15	84
Airports	0	0	0	23	14	0		126	291	454
Vacant	0	0	52	178	32	61		156	38	524
Streets and roads	0	115	204	382	104	82		549	153	1,589
Gross urban and suburban area	0	1,690	1,756	2,389	549	398		7,452	1,056	15,290
<b>Irrigated lands</b>										
Alfalfa	45	57	147	114	83	134		1,304	1,731	3,615
Pasture	0	30	145	108	56	10		233	62	644
Nuts	64	84	330	1,993	2,929	513		1,101	2,796	9,810
Deciduous	0	19	21	24	0	0		38	0	102
Citrus	56	4,031	8,665	6,265	2,540	1,683		5,383	2,921	31,544
Truck	0	59	279	247	158	184		4,171	1,904	7,002
Beans	0	0	327	966	2,232	749		18,149	7,021	29,444
Hay and grain	0	0	7	54	72	0		561	19	713
Nursery	0	8	12	22	2	32		34	85	195
Net irrigated area	165	4,288	9,933	9,793	8,072	3,305		30,974	16,539	83,069
Streets and roads	8	225	523	515	425	174		1,631	870	4,371
Gross irrigated area	173	4,513	10,456	10,308	8,497	3,479		32,605	17,409	87,440
<b>GROSS AREA REQUIRING WATER SERVICE</b>	173	6,203	12,212	12,697	9,046	3,877		40,057	18,465	102,730



TABLE 3c (Continued)

## PRESENT WATER SERVICE AREAS IN VENTURA COUNTY

(In acres)

Class and type of land use	Calleguas-Conejo Hydrologic Unit					Malibu	
	Simi	East Las Posas	West Las Posas	Conejo	Tierra Rejada	Santa Rosa	Totals for
	Subunit	Subunit	Subunit	Subunit	Subunit	Subunit	Hydrologic all hydro-logic units
Urban and suburban lands							
Residential, single	142	110	11	79	3	13	378
Residential, multiple	5	3	3	8	0	5	24
Residential, estate	16	8	6	9	0	6	45
Residential, rural	269	64	11	133	0	0	477
Commercial	17	13	0	40	0	0	70
Industrial, manufacturing	25	32	0	4	0	0	61
Schools	13	10	3	10	0	3	39
Dairies	0	0	0	3	0	0	3
Livestock and poultry ranches	114	107	31	53	7	12	324
Net urban and suburban area	601	347	65	559	10	39	1,421
Military reservations*	0	0	0	0	0	0	0
Industrial, extractive	190	50	0	0	0	0	240
Subdivided, not occupied	0	0	0	10	0	0	10
Airports	12	0	0	0	7	0	19
Vacant	14	18	0	0	0	0	32
Streets and roads	163	90	9	90	0	6	358
Gross urban and suburban area	980	505	74	459	17	45	2,080
Irrigated lands							
Alfalfa	102	99	19	113	0	17	350
Pasture	52	4	48	70	26	2	202
Nuts	2,871	2,257	1,315	556	56	311	7,366
Deciduous	12	183	0	29	0	5	229
Citrus	2,160	2,981	1,445	593	113	1,677	8,969
Truck	256	251	242	104	87	475	985
Beans	205	812	2,606	0	103	186	3,912
Hay and grain	0	0	0	52	0	0	52
Nursery	9	10	0	7	0	4	30
Net irrigated area	5,667	6,597	5,675	1,524	385	2,447	22,095
Streets and roads	297	316	299	81	20	118	1,161
Gross irrigated area	5,964	6,913	5,974	1,605	405	2,365	23,256
GROSS AREA REQUIRING WATER SERVICE	6,944	7,448	6,048	2,064	422	2,410	25,336
							140,328

\* Area of military reservations not segregated by class and type of land use. A small portion of indicated area is estimated to require water service.

TABLE 33

SUMMARY OF PRESENT LAND USE IN HYDROLOGIC UNITS OF  
VENTURA COUNTY

(In acres)

Class of land use	Ventura Hydrologic Unit					
	Upper Ojai : Subunit	Ojai : Subunit	Upper Ventura : River Subunit	Lower Ventura : River Subunit	Rincon : Subunit <sup>a</sup>	Subtotals
<u>Overlying Ground Water Basins</u>						
Gross area requiring water service	160	2,800	1,440	---	---	4,400
Dry farmed and fallow	1,150	1,320	880	---	---	3,350
Native brush and grass	610	1,770	1,540	---	---	3,920
Phreatophytes	30	100	550	---	---	680
Waste land	0	50	580	---	---	630
Water surface	0	0	0	---	---	0
Subtotals	1,950	6,040	4,990	---	---	12,980
<u>Remainder of hydrologic unit</u>						
Gross area requiring water service	140	10	740	5,310	1,140	7,340
Dry farmed and fallow	850	380	5,050	2,120	1,810	10,210
Native brush and grass	6,730	4,360	15,080	23,060	11,950	61,180
Phreatophytes	0	10	110	320	0	440
Waste land	0	0	20	360	490	870
Water surface	0	0	0	0	0	0
Subtotals	7,720	4,760	21,000	31,170	15,390	80,040
TOTALS	9,670	10,800	25,990	31,170	15,390	93,020

TABLE 33 (Continued)

SUMMARY OF PRESENT LAND USE IN HYDROLOGIC UNITS OF  
VENTURA COUNTY

(In acres)

Class of land use	Santa Clara River Hydrologic Unit									
	Eastern : Subunit :	Piru : Subunit :	Fillmore : Subunit :	Santa Paula : Subunit :	Mound : Subunit :	Oxnard Forebay : Subunit :	Oxnard Plain : Subunit :	Pleasant Valley : Subunit :	Subtotals	
<u>Overlying ground water basins</u>										
Gross area requiring water service	0	3,250	10,540	9,840	9,030	3,880	40,060	17,740	94,340	
Dry farmed and fallow	0	160	660	1,590	340	210	950	2,530	6,420	
Native brush and grass	0	1,540	2,220	650	840	910	1,690	2,860	10,510	
Phreatophytes	0	390	1,430	620	300	300	860	290	4,190	
Waste land	0	1,380	1,930	740	590	870	2,900	430	8,840	
Water surface	0	0	90	80	0	0	20	0	190	
Subtotals	0	6,520	16,870	13,520	11,100	6,170	46,460	23,850	124,490	
<u>Remainder of hydrologic unit</u>										
Gross area requiring water service	170	2,950	1,670	2,860	10	0	0	730	8,390	
Dry farmed and fallow	100	1,110	930	1,890	220	0	0	1,670	5,920	
Native brush and grass	2,360	35,940	25,440	33,450	6,160	0	0	9,740	113,090	
Phreatophytes	100	360	410	170	0	0	0	0	1,040	
Waste land	70	430	130	140	0	0	0	20	790	
Water surface	0	0	0	10	0	0	0	0	10	
Subtotals	2,800	40,790	28,580	38,520	6,390	0	0	12,160	129,240	
TOTALS	2,800	47,310	45,450	52,040	17,490	6,170	46,460	36,010	253,730	



TABLE 33 (Continued)

SUMMARY OF PRESENT LAND USE IN HYDROLOGIC UNITS OF  
VENTURA COUNTY

(In acres)

Class of Land use	Calleguas-Conejo Hydrologic Unit										Malibu :	
	Simi Subunit:	East Las Posas Subunit:	West Las Posas Subunit:	Conejo : Subunit:	Tierra Rejada: Subunit:	Santa Rosa: Subunit:	Subtotals:		Hydrologic: Totals for all Units:			
<u>Overlying ground water basins</u>												
Gross area requiring water service	6,180	4,850	5,290	2,060	420	2,040	20,840	---	---	---	---	119,580
Dry farmed and fallow	3,430	1,990	930	11,020	1,540	880	19,790	---	---	---	---	29,560
Native brush and grass	660	700	240	15,790	2,430	120	19,940	---	---	---	---	34,370
Phreatophytes	210	230	10	30	0	30	510	---	---	---	---	5,380
Waste land	270	400	0	20	0	0	690	---	---	---	---	10,160
Water surface	10	0	0	10	0	0	20	---	---	---	---	210
Subtotals	10,760	8,170	6,470	28,930	4,390	3,070	61,790	---	---	---	---	199,260
<u>Remainder of Hydrologic Unit</u>												
Gross area requiring water service	760	2,600	760	0	0	370	4,490	520	520	520	520	20,740
Dry farmed and fallow	4,260	10,960	2,230	0	0	470	17,920	3,340	3,340	3,340	3,340	31,390
Native brush and grass	34,140	30,520	4,700	0	0	4,120	73,480	48,510	48,510	48,510	48,510	296,260
Phreatophytes	70	100	0	0	0	0	170	90	90	90	90	1,740
Waste land	20	130	0	0	0	0	150	120	120	120	120	1,930
Water surface	0	0	0	0	0	0	0	90	90	90	90	100
Subtotals	39,250	44,310	7,690	0	0	4,960	96,210	52,670	52,670	52,670	52,670	358,160
TOTALS	50,010	52,480	14,160	28,930	4,390	8,030	158,000	52,670	52,670	52,670	52,670	557,420

a Lands overlying ground water basins not differentiated.

During the course of the investigation of the water resources of Ventura County conducted by the State between 1927 and 1932 and culminating in Division of Water Resources Bulletin No. 46, similar land use surveys were made. For comparative purposes, Table 34 presents the results of a survey of irrigated crops made in 1931-32 together with those of the 1949-50 survey, tabulated by the three major hydrologic units. It should be noted that the values presented in Table 34 represent gross areas and include roads, farm lots, and other nonproductive lands.

TABLE 34

GROSS AREA OF IRRIGATED CROPS IN MAJOR HYDROLOGIC UNITS OF VENTURA COUNTY,  
1931-32 AND 1949-50

(In acres)

Crop	Ventura		Santa Clara River		Calleguas-Conejo		Totals	
	Hydrologic Unit		Hydrologic Unit		Hydrologic Unit		Hydrologic Unit	
	1931-32	1949-50	1931-32	1949-50	1931-32	1949-50	1931-32	1949-50
Alfalfa	190	235	5,024	3,805	163	368	5,377	4,408
Pasture	22	341	---	678	---	213	22	1,232
Walnuts	276	618	15,430	10,324	6,702	7,753	22,408	18,695
Deciduous	442	145	849	107	2,121	240	3,412	492
Citrus	1,815	2,656	19,503	33,204	4,157	9,441	25,475	45,301
Truck	710	152	17,566	7,371	1,654	1,037	19,930	8,560
Beans	21	35	21,064	30,994	6,358	4,118	27,443	35,147
Hay and grain	164	---	1,113	751	684	55	1,961	806
Nursery	---	14	---	206	---	31	---	251
GROSS IRRIGATED AREA	3,640	4,196	80,549	87,440	21,839	23,256	106,028	114,892



Examination of Table 34 shows that there has been but a small increase in the area of irrigated crops in Ventura County during the 18-year period from 1932 to 1950, particularly in the Ventura and Calleguas-Conejo Hydrologic Units. Except as otherwise qualified, all evaluations relating to water utilization and requirements presented in this bulletin were based on the assumption that the determined present pattern of land use in the County is equivalent to the average pattern prevailing during the base period. Although the overall increase in total irrigated acreage in the County has been relatively small, there have been, however, notable changes in the crop pattern. It is believed that these changes have not materially affected the magnitude of water utilization on irrigated lands. Significant increases in harvested acreages have occurred in the coastal plain of the Santa Clara River Valley, particularly since the end of World War II, as the result of increasing double and triple cropping practices on truck and bean lands. It is estimated that in this area lands not planted to annual crops produce an average of approximately two crops per season. It is considered probable that with maintenance of current farm prices, double and even triple cropping will become increasingly prevalent.

In common with the remainder of California, Ventura County experienced a substantial growth in population during the decade from 1940 to 1950, increasing from 69,685 to 114,647. This influx of people, which appears to be continuing, has been accompanied by a change in land use, particularly in the vicinity of Ventura and Oxnard, where lands formerly occupied by irrigated crops have been and are currently being subdivided for homes and community development. Such a trend is in evidence also in the vicinity of the town of Ojai, and in the Simi and Conejo Subunits of the Calleguas-Conejo Hydrologic Unit, even though the expansion is limited by existing and increasing water supply deficiencies.

Probable Ultimate Pattern of Land Use

Two independent surveys were conducted in Ventura County to determine the nature and extent of the probable ultimate pattern of land use as related to water utilization. A land classification survey was made to ascertain the suitability of lands for irrigated agriculture. In addition, a habitable area survey was conducted to determine the extent of lands not suitable for irrigated agriculture, but susceptible to urban types of development.

The objective of the land classification survey was to delineate the lands suitable for irrigation development and the probable crop pattern that would result with such development. The classification of lands gave consideration to such factors as topography, soils, crop adaptability, and ease of irrigation. It did not consider those economic factors relating to production and marketing, which are variable among given areas and subject to considerable fluctuation over a period of years. The survey encompassed the entire County, and included presently irrigated lands. However, it did not include those areas now devoted to concentrated urban type developments, nor the inaccessible rugged mountainous terrain in the northerly portion of the County, most of which lies within the Los Padres National Forest.

Table 35 presents the standards utilized in the land classification survey.

TABLE 35

## LAND CLASSIFICATION STANDARDS

Land characteristics	Irrigable valley floor lands	Irrigable gently sloping hill lands	Irrigable steeply sloping hill lands	Non-irrigable lands
<u>Soils</u>				
Texture	Loamy sand to permeable clay	Sandy loam to permeable clay	Sandy loam to permeable clay	(Includes all lands which do not meet the minimum requirements for the other classes)
Minimum effective depth of good, free working soil, in inches	18	30	18	
<u>Topography</u>				
Maximum slopes	Smooth slopes up to 6 per cent in general gradient in reasonably large sized bodies sloping in the same plane; or rougher slopes which are less than 4 per cent in general gradient.	Smooth slopes up to 15 per cent in general gradient at minimum soil depths, increasing to 20 per cent as soil depth increases; or rougher slopes which are less than 12 per cent in general gradient.	Smooth slopes up to 30 per cent in general gradient at minimum soil depths, increasing to 45 per cent as soil depth increases; or rougher slopes which are less than 20 per cent in general gradient at minimum soil depths, increasing to 30 per cent as soil depth increases.	
Loose rocks or rock outcroppings	Causing only moderate reduction of productivity and interference with cultural practices.	Causing only slight reduction of productivity and interference with cultural practices.	Same as gently sloping hill lands, except where soils are deep. In that case, moderate reduction of productivity and interference with cultural practices is permitted.	
Erosion	Slight; may have occasional small gullies.	Slight to moderate; may have occasional gullies which are crossable by tillage implements.	Moderate; with very few gullies which are not crossable by tillage implements.	
<u>Drainage</u>				
Soils and topography	Farm drainage may be required.	Drainage not a factor.	Drainage not a factor.	
Salinity	Total salts not to exceed 0.5 per cent, except where reclamation appears feasible.	Salinity not a factor.	Salinity not a factor.	
Alkalinity	pH 9.0 or less, unless soil is calcareous and evidence of black alkali is absent.	Alkalinity not a factor.	Alkalinity not a factor.	



Irrigable valley floor lands of Ventura County are primarily found on alluvial deposits, and generally are of excellent quality. These alluvial soils have been derived from sediments that have undergone little or no change or internal modifications since their deposition, and are still in the process of formation. They are comprised of deposition washed from areas of sand, sandstone, conglomerate, basic igneous rocks, old valley filling deposits, and other rocks within the drainage basins. Adequate depth of soil is present throughout the areal extent of these lands. The topography is smooth and level or gently sloping, and is suitable for most types of irrigation practice. Soil textures vary from medium to heavy, with good water-holding capacity, and the soil structure permits easy penetration of roots, air, and water. Irrigable valley floor lands generally are suitable for continuous production of all climatically adapted irrigated crops.

Irrigable hill lands include those lands which fail to meet the requirements for irrigable valley floor lands in regard to topography, but which are suitable for the production of certain irrigated crops with special irrigation practices. Since these lands are characterized by steep or rolling topography, care must be exercised in their irrigation, and terracing and/or permanent cover crops may be required. Some of these lands are to be found on recent alluvial soils, but for the most part they are comprised of residual soils or old valley filling and coastal plain soil groups that occur in marine or stream terraces. Depths of the soil varies from deep to the minimum allowable, and the underlying material may either be rock, a poorly consolidated material, or a heavy compacted soil with local tendencies toward hardpan. Surface soils are principally medium in texture with a structure permitting ease of penetration of plant roots and water. Irrigable hill lands are primarily suited for crops such as orchard or permanent pasture, which can be irrigated with small heads of water, and cultivated or harvested under adverse topographical conditions. Row crops can be grown on these lands where topography

permits, but extreme care must be exercised when irrigating in order to prevent erosion. Although the development, irrigation, cultivation, and harvesting of crops on these lands will be more difficult than on valley floor lands, they are well suited for crops easily damaged by frost, such as citrus and avocados, in that good air drainage is provided by their topographic characteristics.

Lands which failed to meet the minimum requirements for irrigated agriculture in one or more of the characteristics of soil, topography, or drainage were designated "non-irrigable lands", and were considered unsuitable for irrigation development. These lands include the rugged mountainous areas in the northerly portion of the County, river wash, coastal beach and dune sands, and saline tidal marshes. Certain minor areas located in isolated portions of the County, although meeting the standards for irrigability, were not so classified and were included in the non-irrigable classification.

The term "habitable area", as used herein, refers to those presently undeveloped lands not considered irrigable, but which, by virtue of their topographic characteristics and proximity to either present urban centers or probable future urban areas, were considered susceptible to urban types of development. From the results of a survey conducted throughout the four hydrologic units of Ventura County in 1951-52, it was determined that there were about 6,300 acres of non-irrigable lands which could be considered habitable under this definition.

Results of both the land classification and habitable area surveys indicate that in the four hydrologic units there are about 235,000 acres out of a total area of about 557,000 acres susceptible to concentrated and intensive water-using developments. Plates 24-A, 24-B, and 24-C, entitled "Present and Probable Ultimate Land Use", shows the areal extent of these lands. Table 36 presents the results of the land classification and habitable area surveys conducted in the four hydrologic units.

TABLE 36

CLASSIFICATION OF LANDS IN HYDROLOGIC UNITS OF  
VENTURA COUNTY

(In acres)

Hydrologic unit	Lands susceptible to water service				Non-irrigable lands:		
	Irrigable valley: : floor lands	Irrigable gently: : sloping hill	Irrigable steeply: : sloping hill	Habitable : Present : : Non-irri- : urbana : : gable lands: Lands :	Subtotals	Not susceptible to intensive water: service	Totals
Ventura							
Upper Ojai	590	1,740	1,020	0	3,350	6,320	9,670
Ojai	1,760	2,650	590	650	5,650	5,150	10,800
Upper Ventura River	2,220	4,640	2,460	830	10,150	15,840	25,990
Lower Ventura River	680 <sup>b</sup>	1,310	670	2,550	5,210	25,960	31,170
Rincon	800	---	---	1,610	2,410	12,980	15,390
Subtotals	6,050	10,340	4,740	4,030	26,770	66,250	93,020
Santa Clara River							
Eastern	70	200	40	0	310	2,490	2,800
Piru	3,470	4,270	1,020	110	8,870	38,440	47,310
Fillmore	9,560	5,730	2,730	440	18,460	26,990	45,450
Santa Paula	9,490	3,270	4,510	1,380	18,650	33,390	52,040
Mound	9,140	840	810	460	11,250	6,240	17,490
Oxnard Forebay	4,550	60	0	380	4,990	1,180	6,170
Oxnard Plain	34,640	50	50	4,760	41,840	4,620	46,460
Pleasant Valley	18,040	5,440	1,340	970	25,790	10,220	36,010
Subtotals	88,960	19,860	10,500	8,500	130,160	123,570	253,730
Calleguas-Conejo							
Simi	8,500	3,860	4,180	480	17,020	32,990	50,010
East Las Posas	5,460	8,840	9,420	230	23,950	28,530	52,480
West Las Posas	5,320	4,280	2,190	0	11,790	2,370	14,160
Conejo	1,510	7,650	3,440	280	12,880	16,050	28,930
Tierra Regida	620	680	580	0	1,880	2,510	4,390
Santa Rosa	1,490	1,800	730	0	4,020	4,010	8,030
Subtotals	22,900	27,110	20,540	990	71,540	86,460	158,000
Malibu	2,010	2,420	70	0	6,810	45,860	52,670
TOTALS	119,920	59,730	35,850	13,520	235,280	322,140	557,420

a Concentrated Urban developments. Areas shown do not include all lands designated "urban and suburban" in Table 32.

b Represents total irrigable lands.



It is probable that lands in the four hydrologic units of Ventura County which were not considered either irrigable or habitable, totaling about 322,000 acres, will require water service to some small degree. Although these lands are largely of a rugged topographic character, it was forecast that scattered residences would be found therein under conditions of ultimate development. It was considered that water service to these entities would not be obtained from an organized agency, but rather would be obtained locally from springs or shallow wells through individual effort, and that the effect of these relatively minor uses on the water supply of the County would be negligible.

In addition to the approximately 557,000 acres of land included within the four hydrologic units, there are about 631,000 acres in Ventura County, most of which is in the northerly mountainous region. Of this remaining area, about 620,000 acres are within the boundaries of the Los Padres and Angeles National Forests. It was estimated by the United States Forest Service that there are about 300 acres of irrigable land in the Los Padres National Forest and within the Cuyama River drainage area. In addition, it was determined that there are about 2,000 acres of irrigable land outside the national forest boundaries in the upper reaches of Piru Creek. Under conditions of ultimate development, it is probable that there also will be an increased number of suburban residences and resort-type settlements in the national forest preserves and in the remainder of the County area not included within the four hydrologic units.

Utilizing the results of the land classification and habitable area surveys, and giving consideration to present and probable future trends of development, a pattern of probable ultimate land use was forecast for Ventura County for the purpose of estimating water requirements. As has been shown previously, utilization of water in the County at the present time is predominantly for the needs of agriculture, and the urban requirement is much smaller.

It was concluded, however, that in the future the magnitude of the urban water requirement may approach that of irrigated agriculture. This conclusion was based upon the indicated susceptibility to urbanization of a substantial portion of the County, together with the recent and apparently continuing tremendous growth of population of the nearby Los Angeles Metropolitan Area and of California in general. In this connection, the current rapid change in land use in the adjacent San Fernando Valley from irrigated agriculture to urban and suburban types of community development points to the probability of such an occurrence in portions of Ventura County in the near future. As has been mentioned, a trend in this direction is presently in evidence in areas adjacent to the Cities of Oxnard and Ventura. Accordingly, each hydrologic unit and subunit was studied from a standpoint of its susceptibility to future urbanization. Estimates were made of the percentage of the gross area, classified as requiring future intensive water service, that ultimately would be devoted to urban and suburban types of development. Based on these studies, it was estimated that under ultimate conditions of development in the four hydrologic units of Ventura County, nearly one-half of the lands requiring intensive water service would be used for urban and suburban purposes, with the remainder used for irrigated agriculture.

A probable ultimate pattern of urban land use was then derived, based on percentage factors for the various types of urban development determined in extensive studies of the Los Angeles and San Diego Metropolitan Areas made in connection with preparation of State Water Resources Board Bulletin No. 2. For the probable ultimate irrigated area, a crop pattern was derived based on the results of the land classification survey, crop adaptability, and prevailing trends in irrigated agriculture. Table 37 presents the probable ultimate pattern of land use for each hydrologic unit and subunit in Ventura County.

TABLE 37

PROBABLE ULTIMATE PATTERN OF LAND USE IN HYDROLOGIC UNITS OF  
VENTURA COUNTY

(In acres)

Class and type of land use	Ventura Hydrologic Unit				
	Upper Ojai : Subunit :	Ojai : Subunit :	Upper Ventura : River Subunit :	Lower Ventura : River Subunit :	Rincon : Subunit : Subtotals
<b>Urban and suburban lands</b>					
Residential, single	860	2,160	3,880	1,980	1,230
Residential, multiple	80	210	380	420	120
Residential, estate	80	210	380	100	120
Commercial, strip	80	210	380	260	120
Commercial, downtown	0	0	0	50	0
Industrial, manufacturing	20	40	80	420	20
Schools	30	90	150	160	50
Parks	0	0	0	360	0
Farmsteads	80	70	130	0	0
Net urban and suburban area	1,230	2,990	5,380	3,750	1,660
Airports	20	40	80	100	30
Streets and roads	510	1,280	2,280	1,360	720
Gross urban and suburban area	1,760	4,310	7,740	5,210	2,410
<b>Irrigated lands</b>					
Alfalfa	0	0	0	0	0
Pasture	170	110	490	0	0
Nuts	620	80	210	0	0
Deciduous	570	20	130	0	0
Citrus	40	990	1,300	0	0
Truck	0	0	0	0	0
Beans	0	0	0	0	0
Sugar beets	0	0	0	0	0
Miscellaneous	0	0	0	0	0
Net irrigated area	1,400	1,200	2,130	0	0
Streets and roads and non-productive area	190	140	280	0	0
Gross irrigated area	1,590	1,340	2,410	0	0
Gross area requiring water service	3,350	5,650	10,150	5,210	2,410
Non-irrigable lands not susceptible to intensive water service	6,320	5,150	15,840	25,960	12,990
TOTALS	9,670	10,800	25,990	31,170	15,390
					93,020



TABLE 37 (Continued)

PROBABLE ULTIMATE PATTERN OF LAND USE IN HYDROLOGIC UNITS OF  
VENTURA COUNTY  
(In acres)

Santa Clara River Hydrologic Unit																	
Class and type of land use	Eastern		Piru		Fillmore		Santa Paula		Mound		Forebay		Oxnard		Pleasant Valley		Subtotals
	Subunit		Subunit		Subunit		Subunit		Subunit		Subunit		Subunit		Subunit		
Urban and suburban lands																	
Residential, single	40	1,130	2,360	2,380	3,210	640	7,950	3,290	21,000								
Residential, multiple	0	70	140	140	680	40	1,670	190	2,930								
Residential, estate	0	90	180	190	170	50	420	260	1,360								
Commercial, strip	10	110	230	230	420	60	1,050	320	2,430								
Commercial, downtown	0	0	0	0	80	0	210	0	290								
Industrial, manufacturing	10	180	370	370	680	100	1,670	520	3,900								
Schools	0	70	140	140	250	40	630	190	1,460								
Parks	0	0	0	0	590	0	1,460	0	2,050								
Farmsteads	10	330	690	700	140	190	1,050	970	4,080								
Net urban and suburban area	70	1,980	4,110	4,150	6,220	1,120	16,110	5,740	39,500								
Airports	0	20	50	50	170	10	420	70	790								
Streets and roads	20	550	1,150	1,160	2,190	310	5,440	1,610	12,430								
Gross urban and suburban area	90	2,550	5,310	5,360	8,580	1,440	21,970	7,420	52,720								
Irrigated lands																	
Alfalfa	0	120	240	240	20	230	750	1,530	3,130								
Pasture	0	60	120	120	0	70	190	0	680								
Nuts	100	170	480	2,160	580	540	560	3,070	7,660								
Deciduous	0	110	0	0	0	0	0	0	110								
Citrus	90	4,850	10,270	8,170	940	1,480	2,450	2,050	30,300								
Truck	0	230	480	480	120	230	2,820	3,580	7,940								
Beans	0	0	120	600	630	740	9,790	5,800	17,680								
Sugar beets	0	0	0	0	70	0	1,880	850	2,800								
Miscellaneous	0	170	120	240	50	70	380	170	1,200								
Net irrigated area	190	5,710	11,950	12,010	2,410	3,360	18,820	17,050	71,500								
Streets and roads and non-productive area	30	610	1,200	1,280	260	190	1,050	1,320	5,940								
Gross irrigated area	220	6,320	13,150	13,290	2,670	3,550	19,870	18,370	77,440								
Gross area requiring water service	310	8,870	18,460	18,650	11,250	4,990	41,840	25,790	130,160								
Non-irrigable lands not susceptible to intensive water service	2,490	38,440	26,990	33,390	6,240	1,180	4,620	10,220	123,570								
TOTALS	2,800	47,310	45,450	52,040	17,490	6,170	46,460	36,010	253,730								

TABLE 37 (Continued)

## PROBABLE ULTIMATE PATTERN OF LAND USE IN HYDROLOGIC UNITS OF VENTURA COUNTY

(In acres)

Class and type of land use	Calleguas-Conejo Hydrologic Unit										Totals for	
	Simi	East Las Posas Subunit	West Las Posas Subunit	Conejo Subunit	Tierra Rejada Subunit	Santa Rosa Subunit	Subunit	Subtotals	Hydrologic Unit	Malibu	all hydro-	logic units
<b>Urban and suburban lands</b>												
Residential, single	6,510	3,050	1,500	4,930	240	510		16,740	3,090		50,940	
Residential, multiple	640	180	90	480	10	30		1,430	300		5,870	
Residential, estate	640	240	120	480	20	40		1,540	300		4,090	
Commercial, strip	640	300	150	480	30	50		1,650	300		5,430	
Commercial, downtown	0	0	0	0	0	0		0	0		340	
Industrial, manufacturing	130	480	230	100	40	80		1,060	130		5,540	
Schools	250	180	90	190	10	30		750	130		2,820	
Parks	0	0	0	0	0	0		0	0		2,410	
Farmsteads	210	900	440	160	70	150		1,930	60		6,350	
Net urban and suburban area	9,020	5,330	2,620	6,820	420	890		25,100	4,180		83,790	
Airports	120	60	30	100	0	10		320	60		1,440	
Streets and roads	3,830	1,500	740	2,900	120	250		9,340	820		29,740	
Gross urban and suburban area	12,970	6,890	3,390	9,820	540	1,150		34,760	5,060		114,970	
<b>Irrigated lands</b>												
Alfalfa	0	0	150	0	0	20		170	30		3,330	
Pasture	110	150	80	460	60	30		990	230		2,570	
Nuts	1,800	4,910	1,060	1,170	120	230		9,290	20		17,880	
Deciduous	0	150	80	160	60	30		480	10		1,320	
Citrus	1,550	8,930	3,550	870	780	1,800		17,480	50		50,160	
Truck	0	0	380	0	0	180		560	340		8,840	
Beans	70	750	1,960	50	0	150		2,980	0		20,660	
Sugar beets	0	0	0	0	160	0		160	0		2,960	
Miscellaneous	0	0	300	0	0	130		430	0		1,630	
Net irrigated area	3,530	14,890	7,560	2,710	1,180	2,570		32,440	680		109,350	
Streets and roads and non-productive area	520	2,170	840	350	160	300		4,340	70		10,960	
Gross irrigated area	4,050	17,060	8,400	3,060	1,340	2,870		36,780	750		120,310	
Gross area requiring water service	17,020	23,950	11,790	12,880	1,880	4,020		71,540	6,810		235,280	
Non-irrigable lands not susceptible to intensive water service	32,990	28,530	2,370	16,050	2,510	4,010		86,460	45,860		322,140	
TOTALS	50,010	52,480	14,160	28,930	4,390	8,030		158,000	52,670		557,420	

## Unit Use of Water

The second step in the evaluation of present and probable ultimate water requirements of Ventura County involved determination of appropriate units of water use for each of the classes and types of land use requiring water service. In addition, certain phases of the hydrologic analyses described in Chapter II required determination of use of water by native vegetation and other lands not requiring water service. It should be mentioned that unit values of water use presented in this bulletin are used in conjunction with net areas requiring water service.

### Unit Values of Consumptive Use

Unit values of monthly and seasonal consumptive use of water for both irrigated crops and lands not requiring water service were estimated, utilizing a procedure suggested by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service, United States Department of Agriculture, in their reports entitled "A Method of Estimating Water Requirements in Irrigated Areas from Climatological Data", dated December, 1947, and "Determining Water Requirements in Irrigated Areas from Climatological Data", dated August, 1950. Use of this procedure involved correlation and adjustment of data available on unit seasonal consumptive use by irrigated crops in other localities to correspond with data and conditions prevailing in Ventura County. This included comparison and correlation of data on the basis of variations in average monthly temperatures, monthly percentages of annual daytime hours, precipitation, and length of growing season. It disregarded certain generally unmeasured factors, such as wind movement and humidity. Also utilized were data and analyses appearing in a report to the Ventura County Flood Control District by the United States Department of Agriculture, Soil Conservation Service, entitled "Ground Water Replenishment by Penetration of Rainfall, Irrigation and Water Spreading in



Zone 3, Ventura County Flood Control District, California", and dated April, 1953.

In each of the hydrologic units and subunits, seasonal consumptive use of water for each type of land use, other than urban types, was determined for climatic conditions as they prevailed during the chosen base period from 1936-37 through 1950-51. Values so determined were taken to correspond to values for the mean period. Average unit values of seasonal consumptive use were also determined for the drought period from 1944-45 through 1950-51. In addition, in order to properly analyze hydrology of the ground water basins in the Santa Clara River Hydrologic Unit, it was necessary to estimate unit values of monthly consumptive use for the base period.

Following is an outline of the procedure utilized in estimating unit values of seasonal consumptive use of water by lands requiring water service and native vegetation:

1. The unit value for each irrigated crop during its growing season was taken as the product of available heat and an appropriate coefficient of consumption, where: (a) the available heat was the summation of the products of the average monthly temperatures and the monthly percentages of annual day-time hours, and (b) the coefficient of consumption was one which had been selected as appropriate for this part of California by Harry F. Blaney as a result of his studies for the Soil Conservation Service. Certain modifications were made in the coefficients as a result of studies of consumptive use of water available from other areas.

2. The unit value for each irrigated crop during its non-growing season was taken as the amount of the precipitation available, but not exceeding one to two inches of depth per month, depending upon the crop.

3. The seasonal unit value for each irrigated crop was taken as the summation of values determined under items 1 and 2 for that type.

4. In general, the seasonal unit values for native vegetation were taken as equal to the available precipitation up to about 1.3 feet in depth.

5. The seasonal unit value for phreatophytes was estimated to be five feet of depth, from data appearing in Division of Water Resources Bulletin No. 46, and Division of Water Resources Bulletin No. 44, "Water Losses Under Natural Conditions", dated 1933.

6. Seasonal unit values for free water surfaces were estimated from available records of evaporation at reservoirs in Santa Barbara and Los Angeles Counties. Long-term records of evaporation in Ventura County were not available.

7. Seasonal unit values for remaining miscellaneous nonwater-using types of land use were estimated on the basis of available data on corresponding consumptive uses in similar localities.

8. Seasonal unit values for urban entities were based upon detailed studies conducted in the Los Angeles and San Diego Metropolitan Areas in conjunction with the preparation of State Water Resources Board Bulletin No. 2.

9. Unit values of seasonal consumptive use of applied water were estimated by deducting seasonal effective precipitation from the calculated unit values of total seasonal consumptive use. Initial fall moisture deficiencies for irrigated crops presented in Division of Water Resources Bulletin No. 46 were employed in this determination.

10. In the Santa Clara River Hydrologic Unit, unit values of monthly consumptive use for both lands requiring water service and native vegetation were estimated from the procedure described previously, modified to account for monthly climatic variations.

Table 38 presents the estimated unit values of mean seasonal consumptive use of water and consumptive use of applied water for irrigated lands in Ventura County. Table 39 presents estimates of comparable average seasonal

values for the drought period, while Table 40 presents estimated unit values of mean and drought period seasonal consumptive use of water for native vegetation and other lands not requiring water service.



TABLE 38

ESTIMATED UNIT VALUES OF MEAN SEASONAL CONSUMPTIVE USE OF WATER  
ON IRRIGATED LANDS IN VENTURA COUNTY

(In feet of depth)

Type of land use	Ventura Hydrologic Unit					Santa Clara River Hydrologic Unit					Calleguas-Conejo and Malibu Hydrologic Units				
	Upper Ojai, Ojai, and Upper Ventura River		Lower Ventura River and Rincon Subunits			Eastern, Piru, Fillmore, and Santa Paula Subunits		Mound, Oxnard Forebay Oxnard Plain, and Pleasant Valley Subunits			Calleguas-Conejo and Malibu Hydrologic Units				
	Subunits	Total	Subunits	Total	Subunits	Subunits	Total	Subunits	Total	Subunits	Subunits	Total	Subunits	Total	Subunits
	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:	seasonal use :	Applied:Precipiti-: water : tation :consumptive:
Alfalfa	2.5	1.1	3.6	2.1	1.1	2.4	1.1	3.5	2.1	1.1	2.3	1.1	2.3	1.1	3.4
Pasture	2.5	1.1	3.6	2.1	1.1	2.4	1.1	3.5	2.1	1.1	2.3	1.1	2.3	1.1	3.4
Walnuts	1.6	1.3	2.9	1.6	1.1	1.6	1.2	2.8	1.6	1.1	1.7	1.1	1.7	1.1	2.8
Deciduous	1.5	1.2	2.7	1.3	1.3	1.4	1.2	2.6	1.3	1.3	1.5	1.2	1.5	1.2	2.7
Citrus	1.6	0.9	2.5	1.3	0.9	1.4	1.0	2.4	1.3	0.9	1.3	1.0	1.3	1.0	2.3
Truck <sup>a</sup>	1.2	1.0	2.2	1.0	1.1	1.2	0.9	2.1	1.0	1.1	1.0	1.1	1.0	1.1	2.1
Beans <sup>a</sup>	1.2	1.0	2.2	1.1	1.0	1.2	1.0	2.2	1.1	1.0	1.1	1.1	1.1	1.1	2.2
Hay and grain	---	---	---	0.6	0.9	0.8	0.8	1.6	0.6	0.9	0.6	1.0	0.6	1.0	1.6
Nursery	3.0	1.0	4.0	3.0	1.0	3.0	1.0	4.0	3.0	1.0	3.0	1.0	3.0	1.0	4.0

<sup>a</sup>Values shown are for average of two crops per season.

TABLE 39

ESTIMATED AVERAGE UNIT VALUES OF SEASONAL CONSUMPTIVE USE OF WATER  
ON IRRIGATED LANDS DURING DROUGHT PERIOD IN VENTURA COUNTY

(In feet of depth)

Type of land use	Ventura Hydrologic Unit						Santa Clara River Hydrologic Unit						Calleguas-Conejo and Malibu Hydrologic Units					
	Upper Ojai, Ojai, and Upper Ventura River Subunits			Lower Ventura River and Rincon Subunits			Eastern, Piru, Fillmore, and Santa Paula Subunits			Mound, Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits								
	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use
	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use	: Precipitation : water	: Applied : water	: Total : use
Alfalfa	2.6	1.0	3.6	2.4	0.7	3.1	2.6	0.8	3.4	2.4	0.7	3.1	2.7	0.6	3.3			
Pasture	2.6	1.0	3.6	2.4	0.7	3.1	2.6	0.8	3.4	2.4	0.7	3.1	2.7	0.6	3.3			
Walnuts	1.8	1.1	2.9	2.0	0.8	2.8	1.9	0.9	2.8	2.0	0.8	2.8	2.1	0.7	2.8			
Deciduous	1.7	1.0	2.7	1.8	0.8	2.6	1.8	0.8	2.6	1.8	0.8	2.6	1.9	0.8	2.7			
Citrus	1.7	0.8	2.5	1.4	0.9	2.3	1.5	0.8	2.3	1.4	0.9	2.3	1.6	0.6	2.2			
Truck <sup>a</sup>	1.2	0.9	2.1	1.3	0.8	2.1	1.2	0.9	2.1	1.3	0.8	2.1	1.4	0.7	2.1			
Beans <sup>a</sup>	1.3	0.7	2.0	1.3	0.8	2.1	1.2	1.0	2.2	1.3	0.8	2.1	1.5	0.7	2.2			
Hay and grain	---	---	---	0.7	0.8	1.5	0.8	0.7	1.5	0.7	0.8	1.5	0.7	0.9	1.6			
Nursery	3.0	1.0	4.0	3.0	1.0	4.0	3.0	1.0	4.0	3.0	1.0	4.0	3.0	1.0	4.0			

<sup>a</sup>Values shown are for average of two crops per season.

TABLE 40

ESTIMATED UNIT VALUES OF SEASONAL CONSUMPTIVE USE OF  
WATER ON NON-IRRIGATED LANDS IN VENTURA COUNTY

(In feet of depth)

Type of Land use	Ventura Hydrologic Unit			Santa Clara River Hydrologic Unit			Calleguas-Conejo and Malibu Hydrologic Units			
	: Mean : Drought period: Mean : Drought period: Mean : Drought period:			: Mean : Drought period: Mean : Drought period: Mean : Drought period:			: Mean : Drought period: Mean : Drought period: Mean : Drought period:			
	: Upper Ojai, Ojai, and Upper Ventura River : Lower Ventura River : Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits :			: Upper Ojai, Ojai, and Upper Ventura River : Lower Ventura River : Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits :			: Upper Ojai, Ojai, and Upper Ventura River : Lower Ventura River : Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits :			
	Upper Ojai, Ojai, and Upper Ventura River	Lower Ventura River	Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits	Upper Ojai, Ojai, and Upper Ventura River	Lower Ventura River	Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits	Upper Ojai, Ojai, and Upper Ventura River	Lower Ventura River	Eastern, Piru, Fillmore, and Oxnard Plain, and Mound, Oxnard Forebay, and Pleasant Valley Subunits	
Non-irrigated agriculture	1.3	1.1	1.3	0.8	1.3	0.9	1.3	0.8	1.2	0.8
Fallow	0.7	0.5	0.6	0.4	0.6	0.5	0.6	0.4	0.6	0.4
Abandoned crop land	1.3	1.1	1.3	0.8	1.3	0.9	1.3	0.8	1.2	0.8
Native brush and grass	1.3	1.1	1.3	0.8	1.3	0.9	1.3	0.8	1.2	0.8
Phreatophytes	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
River wash	0.7	0.5	0.6	0.4	0.6	0.5	0.6	0.4	0.6	0.4
Water surface	4.2	4.4	4.2	4.4	4.2	4.4	4.2	4.4	4.2	4.4



Presented in Table 41 are estimated mean seasonal unit values of water delivery to and consumptive use of water on urban and suburban types of land use. Drought period values for urban and suburban types of land use were not estimated, since the effect of varying climatic conditions on use of water by these types was considered insignificant in Ventura County. As mentioned previously, values presented in Table 41 were derived from detailed studies of water use by urban types of development in the Los Angeles and San Diego Metropolitan Areas. Values for unit delivery requirements shown in Table 41, although probably representative of ultimate unit delivery requirements for urban types of development, appear to be greater than present deliveries in the service area of the City of Ventura and in the Rincon Subunit, in the cases of multiple residences, strip and downtown commercial, and industry of a manufacturing nature. For present conditions of development in the portions of the County where applied water was taken as the measure of water requirement, records of historical water deliveries rather than the units presented in Table 41 were utilized in estimating water requirements. However, as described hereinafter, these units were employed in estimating probable ultimate water requirements.

TABLE 41

ESTIMATED MEAN SEASONAL UNIT DELIVERY TO AND CONSUMPTIVE  
USE OF WATER ON URBAN AND SUBURBAN LANDS IN VENTURA COUNTY

(In feet of depth)

Type of land use	: Delivery	Consumptive use		
		: Applied water	: Precipitation	: Total
Residential, single	2.8	1.3	0.9	2.2
Residential, multiple	5.0*	0.3	0.6	0.9
Residential, estate	2.2	1.5	1.1	2.6
Residential, rural	1.8	0.8	0.8	1.6
Commercial, strip	4.0*	0.4	0.5	0.9
Commercial, downtown	11.0*	1.1	0.5	1.6
Industrial, manufacturing	8.5*	1.4	0.6	2.0
Schools	1.1	0.4	0.7	1.1
Parks	2.2	1.7	0.9	2.6
Dairies	1.9	1.0	0.9	1.9
Livestock and poultry ranches	1.3	0.6	0.7	1.3
Industrial, extractive	0.0	0.0	0.6	0.6
Subdivided, not occupied	0.0	0.0	0.6	0.6
Airports	0.0	0.0	0.5	0.5
Vacant	0.0	0.0	0.6	0.6
Streets and roads	0.0	0.0	0.5	0.5

\* Not applicable under present conditions of development in service area of City of Ventura and in Rincon Subunit.

Unit Values of Applied Water

In certain portions of Ventura County, it was necessary to determine appropriate unit values of applied water to furnish a basis for estimating water requirements, particularly for probable ultimate conditions of development. To this end, records of water applied to representative crops available from mutual water companies, ranches, private individuals, and publications of the Division of Water Resources and other agencies were analyzed. Field studies of water applied to predominant irrigated crops were also conducted during the course of the investigation. Records of historical deliveries of water to principal urbanized areas, such as Ventura and Oxnard, were obtained and analyzed. Data

regarding delivery requirements for urban entities in the Los Angeles and San Diego Metropolitan Areas were also employed, the results of which are shown in Table 41.

The results of the studies for irrigated crops indicated a definite relationship between the amount of water applied to a given crop and the amount and occurrence of rainfall in a given season. Furthermore, extreme variations were noted in the amounts of water applied to a given crop in the same season among several users. These variations resulted from differences in irrigation practice, soil types, and individual preference and skill among irrigators, and were of such an indeterminable nature that an accurate accounting thereof was impossible.

Presented in Table 42 are estimated average unit seasonal values of application of irrigation water on principal crops in Ventura County during both the drought and wet periods. Also shown are arithmetical averages of the values for these two periods, which averages were taken as being equivalent to mean seasonal irrigation applications. While it is known that many exceptions and substantial variations from the estimated values occur, they are nevertheless considered to be representative of present irrigation practices in the County.



TABLE 42

ESTIMATED UNIT VALUES OF SEASONAL APPLICATION  
OF IRRIGATION WATER ON PRINCIPAL CROPS  
IN VENTURA COUNTY

(In feet of depth)

Hydrologic unit and subunit	Crop	Average for drought period	Average for wet period	Mean
Ventura	Citrus	2.5	---	---
Santa Clara River				
Eastern, Piru,	Citrus	2.8	2.2	2.5
Fillmore, and Santa	Walnuts	1.0	.5	.8
Paula Subunits	Alfalfa	5.4	4.8	5.1
	Truck	3.1	2.2	2.6
Mound, Oxnard Fore-	Citrus	1.4	1.3	1.4
bay, Oxnard Plain,	Walnuts	1.7	1.5	1.6
and Pleasant Valley	Beans	1.4	1.2	1.3
Subunits	Truck	2.0	1.2	1.6
Calleguas-Conejo	Citrus	1.9	1.4	1.6
	Walnuts	1.2	.8	1.0
	Alfalfa	---	---	3.0
	Beans	---	---	1.1
	Truck	---	---	1.2

Substantiation of the values for applied water presented in Tables 41 and 42 was obtained from the Mound, Oxnard Plain, and Pleasant Valley Subunits for the drought period from 1944-45 through 1950-51. Detailed studies were made to determine ground water extractions in these subunits for each season from 1944-45 through 1951-52. This study was conducted in cooperation with the Southern California Edison Company and included analyses of power consumption by agricultural, municipal, and other major plants pumping from ground water, pumping plant efficiencies, the results of about 580 pump tests available from the Southern California Edison Company, and of data on pumping lifts obtained from analysis of measurements of depth to ground water made during the period of

study by the Ventura County Water Survey. By applying unit values of applied water considered representative of the drought period to determined irrigated crop acreages, and by making similar computations for urban and suburban lands, it was estimated that 102,000 acre-feet of water per season on the average were applied on the Mound, Oxnard Plain, and Pleasant Valley Subunits during the drought period. In these computations, an additional allowance was made for the use of the American Crystal Sugar Company's plant at Oxnard, which was estimated to be substantially in excess of the unit delivery factor of 8.5 feet of depth indicated in Table 41. The average seasonal pumpage during this period corrected for imports to and exports from the three subunits was estimated to have been about 107,500 acre-feet. In view of the nature of the basic data, the check furnished was believed to be reasonably close, and the average unit values of seasonal application of water to prevailing types of land use were considered representative for the drought period in these subunits.

Presented in the following tabulation are estimated present weighted average seasonal unit values of applied water in the Mound, Oxnard Plain, and Pleasant Valley Subunits for drought, wet, and mean periods:

	Seasonal unit values of applied water, in feet of depth		
	<u>Urban lands</u>	<u>Irrigated lands</u>	<u>Weighted average for urban and irrigated lands</u>
Drought period	4.3	1.7	1.8
Wet period	4.3	1.2	1.3
Mean period	4.3	1.4	1.6

#### Water Requirements

Estimates of present and probable ultimate water requirements in Ventura County were made by applying appropriate unit values of water use to the present and probable ultimate areas requiring water service, and by utilizing

historical records or estimates of water production. In portions of the County wherein water applied to lands in excess of consumptive use will either return to ground water storage and be available for re-use, or will drain from the area under consideration and be available for re-use downstream, the measure of water requirement was taken as the amount of consumptive use of applied water. For lands overlying confined ground water basins, wherein it was assumed that water applied in excess of consumptive use is prevented from returning to ground water storage for subsequent re-use, the measure of water requirement was taken as the amount of applied water. Similarly, for other portions of the County not overlying ground water basins, wherein the unconsumed residuum of water applied either drains directly to the ocean or is discharged thereto as sewage effluent, water requirements were measured in terms of applied water.

Water requirements in Ventura County were evaluated for the conditions of water supply and climate that would prevail with repetition of the base period, and also for conditions that would occur during a period of drought as that from 1944-45 through 1950-51, under both present and probable ultimate patterns of land use. In many water resources studies, water requirements for a given stage of development are determined only for a mean period or for a base period which is considered representative of mean conditions. In Ventura County, however, and in similar areas subject to wide extremes in seasonal water supplies and climatic conditions, with particular regard to precipitation, water requirements for irrigation are substantially increased during periods of drought when the natural supply from direct rainfall is reduced. This results in a marked increase in the demand for artificial water supplies from either surface or ground water sources. Thus, for such irrigated areas, drought period water requirements are of particular significance in planning for water supply development. As stated previously, for purposes of analysis in this bulletin, it was assumed that urban and suburban water requirements are not appreciably affected by such seasonal and cyclic climatic variations.



## Present Water Requirements

The present mean seasonal water requirement of Ventura County was estimated to be about 180,000 acre-feet. It was further estimated that during drought periods this requirement would increase to about 205,000 acre-feet per season.

Determination of the present mean and drought period seasonal water requirements was based on the following assumptions:

1. That the nature and extent of land use in Ventura County determined from the land use survey of 1949-50 is representative of present conditions of development.
2. That average conditions of water supply and climate during the base period were representative of mean conditions, and that present average seasonal water requirements determined for base period conditions of water supply and climate are equivalent to present mean seasonal water requirements.
3. That present average seasonal water requirements estimated for conditions of water supply and climate prevailing during the period from 1944-45 through 1950-51 are equivalent to present seasonal water requirements during a drought period.
4. That deficiencies in the estimated seasonal water requirements for both urban and suburban and irrigated lands cannot be endured.
5. That the estimated gross production of water by the City of Ventura during the season of 1950-51 of about 5,700 acre-feet represents the present seasonal water requirement of the service area of that City.
6. That the average seasonal extractions of ground water in Mound, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit, during the period from 1944-45 through 1950-51, corrected for exports and imports, are equivalent to the present seasonal water requirements therein during a drought period.

7. That the average of the estimated seasonal extractions of ground water from the Mound, Oxnard Plain, and Pleasant Valley Basins for the two seasons of 1944-45 and 1951-52, corrected for exports and imports, are equivalent to the average present seasonal water requirements therein during a wet period.

8. That the arithmetical average of the seasonal water requirements during the base period for the Mound, Oxnard Plain, and Pleasant Valley Subunits, determined under the assumptions of items 6 and 7, are equivalent to the present mean seasonal water requirements therein.

In the Upper Ojai, Ojai, and Upper Ventura River Subunits of the Ventura Hydrologic Unit, wherein water applied in excess of consumptive use will either return to ground water storage and be available for re-use, or will drain to Ventura River and be susceptible to capture by ground water users in Upper Ventura River Basin or surface diverters along the Ventura River, present water requirements were estimated from unit values of consumptive use of applied water. For the Lower Ventura River and Rincon Subunits, wherein excess water is drained to the ocean or discharged thereto as sewage effluent, present water requirements were estimated and assumed to be measured by total application of water.

Present water requirements in the Eastern, Piru, Fillmore, Santa Paula, and Oxnard Forebay Subunits of the Santa Clara River Hydrologic Unit and in Calleguas-Conejo and Malibu Hydrologic Units, were taken equal to the estimated consumptive use of applied water therein, since reregulation of the unconsumed portion of applied water is obtained in prevailing free ground water basins. As mentioned previously, present water requirements for the Mound, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit were evaluated from estimates of total applied water. Table 43 presents the results of the evaluation of water utilization in the Mound, Oxnard Plain,

and Pleasant Valley Subunits during the period from 1944-45 through 1951-52, which data were used in determining present water requirements therein.



TABLE 43

ESTIMATED SEASONAL UTILIZATION OF WATER IN MOUND, OXNARD PLAIN,  
AND PLEASANT VALLEY SUBUNITS FROM 1944-45 THROUGH 1951-52

(In acre-feet)

Season	Mound Subunit			Oxnard Plain Subunit			Pleasant Valley Subunit		
	1	2	3	4	5	6	7	8	
	: Import from Santa:			: Export to:			: Applied water:		
	: Ground water: Paula and Oxnard:			: Calleguas-Conejo:			: Import from Santa:		
	: extractions:			: Hydrologic Unit:			: Paula Subunit:		
	: Forebay Subunits: (1 & 2)			: extractions:			: (4 - 5 & 6):		
	: tions = applied water								
1944-45	7,700	2,400	10,100	46,700	1,000	200	45,900	20,700	
1945-46	10,900	2,800	13,700	63,000	1,500	500	62,000	28,300	
1946-47	11,900	3,200	15,100	65,900	1,600	700	65,000	30,600	
1947-48	14,300	3,800	18,100	64,000	2,100	600	62,500	34,900	
1948-49	13,900	3,600	17,500	66,100	700	700	64,900	39,300	
1949-50	11,500	2,800	14,300	57,500	1,300	400	56,600	32,100	
1950-51	12,000	3,500	15,500	66,900	1,900	200	65,200	39,900	
1951-52	4,700	2,100	6,800	46,800	800	300	46,300	22,700	
Average for drought period, 1944-45 through 1950-51	11,800	3,100	14,900	61,400	1,600	500	60,300	32,300	
Average for seasons, 1944-45 and 1951-52	6,200	2,300	8,500	46,700	900	300	46,100	21,700	

It should be mentioned that examination of records of irrigation application to walnuts in the Simi Subunit of the Calleguas-Conejo Hydrologic Unit indicated that during the base period insufficient water was applied to meet the consumptive requirement of this crop. It was estimated that about 2,900 acre-feet of irrigation water per season were actually consumed during the base period by lands planted to walnuts, as compared to an estimated consumptive requirement for irrigation water by these lands of about 5,100 acre-feet per season. Thus, the present water requirement was estimated to be about 2,200 acre-feet per season greater than actual present use in the Simi Subunit.

Table 44 presents the estimated present mean and drought period seasonal water requirements for each of the hydrologic units and subunits in Ventura County, as determined from the foregoing methods and assumptions.

TABLE 44

ESTIMATED PRESENT MEAN AND DROUGHT PERIOD  
SEASONAL WATER REQUIREMENTS IN VENTURA COUNTY

(In acre-feet)

Hydrologic unit and subunit	Mean			Drought period		
	:Urban and: :suburban	:Irrigated : :agriculture:	:Totals	:Urban and: :suburban	:Irrigated : :agriculture:	:Totals
Ventura						
Upper Ojai	100	300	400	100	300	400
Ojai	600	2,900	3,500	600	3,000	3,600
Upper Ventura River	800	1,900	2,700	800	2,000	2,800
Lower Ventura River	4,100	2,100	6,200	4,100	2,100	6,200
Rincon	200	300	500	200	300	500
Subtotals	5,800	7,500	13,300	5,800	7,700	13,500
Santa Clara River						
Eastern	0	300	300	0	300	300
Piru	200	7,000	7,200	200	7,400	7,600
Fillmore	500	13,800	14,300	500	14,700	15,200
Santa Paula	1,100	14,600	15,700	1,100	15,700	16,800
Mound	400	11,100	11,500	400	14,500	14,900
Oxnard Forebay	300	4,200	4,500	300	4,400	4,700
Oxnard Plain	9,700	43,000	52,700	9,700	50,600	60,300
Pleasant Valley	700	25,900	26,600	700	31,600	32,300
Subtotals	12,900	119,900	132,800	12,900	139,200	152,100
Calleguas-Conejo						
Simi	600	9,100	9,700	600	10,100	10,700
East Las Posas	400	9,400	9,800	400	11,100	11,500
West Las Posas	100	7,000	7,100	100	8,600	8,700
Conejo	300	2,300	2,600	300	2,900	3,200
Tierra Rejada	0	500	500	0	700	700
Santa Rosa	0	3,100	3,100	0	4,000	4,000
Subtotals	1,400	31,400	32,800	1,400	37,400	38,800
Malibu	200	600	800	200	700	900
TOTALS*	20,300	159,400	179,700	20,300	185,000	205,300

\* Present water requirements for minor water service areas not included within hydrologic units were estimated to average less than 100 acre-feet per season.



## Probable Ultimate Water Requirements

Probable ultimate mean and drought period seasonal water requirements of Ventura County were estimated to be about 389,000 acre-feet and about 420,000 acre-feet, respectively. For the probable ultimate water service areas in the four hydrologic units, water requirements were estimated by multiplying the predicted acreages of each type of land use by appropriate unit values of seasonal water use. However, the foregoing estimates of water requirements also include allowances for expected minor water-using entities, scattered throughout the four hydrologic units and the remainder of the County, and not requiring intensive water service. In general, these minor allowances were estimated on the basis of population density-water use relationships. Requirements for predicted minor irrigation developments were estimated in the same manner as for other probable ultimate irrigated lands.

For water service areas in the Upper Ojai, Ojai, and Upper Ventura River Subunits of the Ventura Hydrologic Unit, ultimate water requirements were estimated by application of appropriate unit values of consumptive use of applied water to predicted ultimate water-using lands. For the Rincon and Lower Ventura River Subunits, unit values of applied water were utilized.

In the Eastern, Piru, Fillmore, Santa Paula, and Oxnard Forebay Subunits of the Santa Clara River Hydrologic Unit, unit values of consumptive use of applied water were employed, while unit values of applied water were used in the Mound, Oxnard Plain, and Pleasant Valley Subunits. Unit values of applied water for irrigated crops in these latter subunits were estimated by applying a 70 per cent irrigation efficiency to computed values of consumptive use of applied water.

In water service areas of the Simi, East and West Las Posas, Tierra Rejada, and Santa Rosa Subunits of the Calleguas-Conejo Hydrologic Unit, ultimate water requirements were estimated by application of appropriate unit values

of consumptive use of applied water, increased by 25 per cent to allow for waste from these areas necessary to maintain a favorable salt balance in ground water basins and for possible exportation of sewage effluent, which latter occurrence could result with increased urbanization. In the Conejo Subunit, ultimate water requirements were estimated by multiplying acreages of each type of land use requiring water service by respective unit values of applied water. It is believed that the utility of ground water storage in the Conejo Basin is limited by irregularities in the fracture system in the volcanic rocks from which ground water supplies are principally obtained. It is probable that with increased development of the subunit, the uncertainties attendant upon utilization of these ground water supplies will render them of minor significance in water supply utilization and regulation, and that water service will primarily be obtained from other sources.

For reasons similar to those cited in the case of the Conejo Subunit, ultimate water requirements of the Malibu Hydrologic Unit were determined by multiplying acreages of each type of land use requiring water service by respective unit values of applied water.

For those lands in the hydrologic units not requiring intensive water service under probable ultimate conditions of development, but wherein scattered residences were forecast, an ultimate mean seasonal water requirement of about 1,100 acre-feet was estimated from population density-water use relationships. For lands in the Los Padres and Angeles National Forests not included within the hydrologic units, the United States Forest Service has estimated a probable ultimate mean seasonal water requirement of approximately 900 acre-feet, including the requirement for about 300 acres of irrigated land. Other potential water-using lands in Ventura County, not included within the federal reservation or in the four hydrologic units comprising a gross area of about 11,000 acres, including a probable ultimate net area requiring water service of about 1,700

acres in the Upper Piru Creek drainage area, were estimated to have a probable ultimate mean seasonal water requirement of about 2,800 acre-feet.

Table 45 summarizes by hydrologic unit and subunit the estimates of probable ultimate mean and drought period seasonal water requirements.



TABLE 45

ESTIMATED PROBABLE ULTIMATE MEAN AND DROUGHT PERIOD  
SEASONAL WATER REQUIREMENTS IN VENTURA COUNTY

(In acre-feet)

Hydrologic unit and subunit	Mean			Drought period		
	Urban and: suburban	Irrigated : agriculture:	Totals	Urban and: suburban	Irrigated : agriculture:	Totals
Ventura						
Upper Ojai	1,400	2,300	3,700	1,400	2,600	4,000
Ojai	3,500	2,300	5,800	3,500	2,500	6,000
Upper Ventura River	6,100	3,900	10,000	6,100	4,100	10,200
Lower Ventura River	14,000	0	14,000	14,000	0	14,000
Rincon	<u>5,000</u>	<u>0</u>	<u>5,000</u>	<u>5,000</u>	<u>0</u>	<u>5,000</u>
Subtotals	30,000	8,500	38,500	30,000	9,200	39,200
Santa Clara River						
Eastern	100	300	400	100	300	400
Piru	2,200	9,100	11,300	2,200	9,200	11,400
Fillmore	4,600	16,100	20,700	4,600	17,400	22,000
Santa Paula	4,700	16,500	21,200	4,700	18,100	22,800
Mound	22,500	4,400	26,900	22,500	5,200	27,700
Oxnard Forebay	1,200	4,500	5,700	1,200	5,200	6,400
Oxnard Plain	59,800	31,200	91,000	59,800	37,100	96,900
Pleasant Valley	<u>18,400</u>	<u>31,800</u>	<u>50,200</u>	<u>18,400</u>	<u>39,200</u>	<u>57,600</u>
Subtotals	113,500	113,900	227,400	113,500	131,700	245,200
Calleguas-Conejo						
Simi	12,900	7,200	20,100	12,900	7,900	20,800
East Las Posas	7,500	26,300	33,800	7,500	31,200	38,700
West Las Posas	3,700	12,000	15,700	3,700	14,400	18,100
Conejo	20,500	6,100	26,600	20,500	7,800	28,300
Tierra Rejada	600	2,000	2,600	600	2,700	3,300
Santa Rosa	<u>1,200</u>	<u>4,300</u>	<u>5,500</u>	<u>1,200</u>	<u>5,700</u>	<u>6,900</u>
Subtotals	46,400	57,900	104,300	46,400	69,700	116,100
Malibu	12,300	1,400	13,700	12,300	1,800	14,100
Remainder of County*	1,800	3,000	4,800	1,800	3,500	5,300
TOTALS	204,000	184,700	388,700	204,000	215,900	419,900

\* Includes scattered residences throughout County, together with about 2,000 acres of land requiring water service in Cuyama River drainage area and in upper reaches of Piru Creek drainage area.

## Demands for Water

The term "demands for water", as used in this bulletin, refers to those factors pertaining to rates, times, and places of delivery of water, losses of water, quality of water, etc., imposed by the control, development, and use of water for beneficial purposes. Those demands relating to times, rates, and delivery of water, and permissible deficiencies in application of water must be given consideration in preliminary design of works to meet supplemental water requirements and are, therefore, discussed in the following sections. Demands relating to application of water to satisfy beneficial use have been discussed previously.

### Monthly Demands for Water

Because of the erratic occurrence of precipitation and stream flow in Ventura County, both seasonally and monthly, there is wide variation in the monthly percentage of seasonal irrigation demand. Wide variations also prevail both in the rate and period of demand for irrigation water for different crops. Generally, most irrigation water is applied during the months from April to November. However, the increasing double and triple cropping practices in the coastal plain of the Santa Clara River Valley impose demands on artificial water supplies throughout the year. Furthermore, with diminution of winter rainfall during protracted periods of drought, perennial crops such as citrus, deciduous orchard, and irrigated pasture require winter irrigation to supplement deficiencies in natural supplies. However, during a year of subnormal rainfall, with expedient distribution, winter irrigation may not be practiced. In the aforementioned coastal plain of the Santa Clara River Valley, if there has been insufficient precipitation in the spring to achieve proper soil moisture conditions, it is common practice to pre-irrigate bean land prior to planting. With

heavy spring precipitation, beans are not usually pre-irrigated, and the requirement for ground water supplies in such a season is substantially reduced.

Studies of irrigation practice in Ventura County indicate that for certain crops the monthly percentages of seasonal demand for water have varied from zero in the minimum month to as high as 33 per cent in the maximum month. During drought periods, although monthly percentages of seasonal demand have been more uniform throughout the season, total amounts of applied water have been greater. Since use of water in urban areas is influenced only slightly by the magnitude and occurrence of precipitation, monthly percentages of seasonal demand for urban water remain rather constant seasonally, and also show a more uniform monthly distribution than do monthly irrigation demands.

Presented in Table 46 are estimates of average monthly distribution of seasonal demands for irrigation water for mean and drought periods, together with those for average monthly distribution of seasonal demand for urban water. Estimates of monthly urban demands were based on analysis of water deliveries and water production by the Cities of Ventura, Port Hueneme, and Oxnard. Irrigation demands were estimated from data obtained from representative water service agencies, mutual water companies, and individual consumers, and from analysis of records of agricultural power consumption obtained from the Southern California Edison Company.



TABLE 46

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF  
DEMANDS FOR URBAN AND IRRIGATION WATER IN VENTURA COUNTY

(In per cent of seasonal total)

Month	Urban demands	Irrigation demands					
		Eastern, Piru, Fillmore, and Santa Paula Subunits,	Mound, Oxnard Forebay, and Pleasant :	Oxnard Plain, and Pleasant :	Valley Subunits, Santa Clara River Hydrologic Unit <sup>b</sup> :	Mean : Drought period	Mean : Drought period
October	8.8	10.3	10.7	8.8	10.4	9.0	8.8
November	7.7	9.2	8.2	7.3	8.4	6.6	6.6
December	6.7	6.6	6.1	5.1	6.4	3.2	3.0
January	6.3	3.0	4.3	1.8	4.5	1.7	2.2
February	6.0	1.0	1.7	0.9	3.4	1.6	2.3
March	6.9	2.3	4.4	2.7	4.3	3.5	4.6
April	7.7	3.1	4.8	6.1	7.2	5.1	7.3
May	8.9	12.0	12.3	12.2	10.0	11.5	12.8
June	10.3	12.5	10.3	13.2	10.6	14.0	12.8
July	10.6	14.6	13.1	15.4	10.7	15.2	14.4
August	10.7	13.4	13.5	14.7	11.9	14.9	13.1
September	9.4	12.0	10.6	11.8	12.2	13.7	12.1
TOTALS	100.0	100.0	100.0	100.0	100.0	100.0	100.0

<sup>a</sup>Estimated to be applicable in Upper Ojai, Ojai, and Upper Ventura River Subunits of Ventura Hydrologic Unit.<sup>b</sup>Estimated to be applicable in Lower Ventura River and Rincon Subunits of Ventura Hydrologic Unit.<sup>c</sup>Estimated to be applicable in Malibu Hydrologic Unit.

## Irrigation Efficiency

Satisfaction of the consumptive requirements of irrigated crops requires the application of water in excess of consumptive use. The ratio of consumptive use of applied water to the total amount of applied water, expressed as a percentage, is termed "irrigation efficiency", and is useful as an indicator of prevailing irrigation practice. Irrigation efficiency varies widely between crops and among plots devoted to the same crop. These variations are accounted for in differences of root depth, soil type, topography, method of irrigation, drainage characteristics, and in the practices of the individual irrigators. During the course of this investigation, studies were made in selected areas by both the Division of Water Resources and by the United States Soil Conservation Service to ascertain approximate irrigation efficiencies. The Soil Conservation Service in their report, "Ground Water Replenishment by Penetration of Rainfall, Irrigation and Water Spreading in Zone 3, Ventura County Flood Control District, California", dated April, 1953, estimated the average irrigation efficiency during the base period for predominant crops in the Pleasant Valley Subunit of the Santa Clara River Hydrologic Unit, and for the several subunits of the Calleguas-Conejo Hydrologic Unit.

The estimates of the Soil Conservation Service were made by comparison of records of actual application of water to crops and estimated optimum values of consumptive use of applied water. These studies indicated that irrigation efficiencies of 85 to 90 per cent prevailed for citrus, 95 to 100 per cent for walnuts, 74 to 77 per cent for alfalfa and irrigated pasture, 58 to 64 per cent for beans, and 70 to 75 per cent for summer truck crops. In the case of walnuts, it appears probable that actual consumptive use of applied water was less than the computed values used in the studies, and that actual irrigation efficiency was less than the foregoing figures indicate.

It is known that even under the most favorable conditions a 100 per cent irrigation efficiency can rarely or never be achieved. Application of water sufficient to meet consumptive requirements will result in either deep penetration beyond the root zone of the crop under irrigation, or waste from the lower end of the field. Comparison of records of application of water with estimates of consumptive use of applied water in the Piru, Fillmore, and Santa Paula Subunits of the Santa Clara River Hydrologic Unit indicates that irrigation efficiencies on citrus approximate 60 per cent. Irrigation efficiencies on citrus and walnuts in excess of this value were noted in the Oxnard Plain Subunit. However, in this area, it is possible that these crops draw upon rainfall percolation and return irrigation water stored in the semi-perched ground water body, thereby reducing applied water requirements and increasing the apparent irrigation efficiencies.

In general, it is believed that, with the cited exceptions, an overall irrigation efficiency of about 70 per cent is being achieved in Ventura County at the present time.

#### Irrecoverable Losses

Attendant with the beneficial use of water, including the irrigation of crop land and the delivery of urban and suburban supplies, there may occur certain losses of water which cannot be recovered for further beneficial use. As used in this bulletin, the term "irrecoverable losses of water" refers to the water applied to irrigated crops in excess of beneficial consumptive use in confined ground water areas, wherein re-use cannot be effected, and to the sewage effluent from urbanized areas which is discharged to the ocean or otherwise lost for re-use, together with any transmission or delivery losses incurred, which are not susceptible to re-use. These losses comprise an additional demand on the supplies of Ventura County over and above consumptive uses. Comparison of



present consumptive use of applied water with estimated present water requirements in Ventura County indicates that present mean seasonal irrecoverable losses amount to about 22,000 acre-feet.

#### Permissible Deficiencies in Application of Water

Studies to determine deficiencies in the supply of irrigation water that might be endured without permanent injury to perennial crops were not made in connection with the Ventura County Investigation. However, such studies have been made for other areas in California, and indicate that a maximum deficiency of 35 per cent of the full seasonal requirement can be endured if the deficiency occurs only at relatively long intervals. It has also been determined that small deficiencies occurring at relatively frequent intervals can be endured.

In connection with the studies for this bulletin, no allowances were made for deficiencies in water supply. Even though it is known that portions of Ventura County subsisted on deficient water supplies during the latter years of the recent drought period, all estimates pertaining to water requirements were based upon the assumption that adequate water supplies would be provided to produce optimum crop yields each and every year. Similarly, estimates of requirements for urban and suburban entities did not allow for deficiencies in supply.

#### Supplemental Water Requirements

As has been stated, the security of existing developments and economies in Ventura County is threatened by water supply shortages which develop

during periods of drought, by perennial lowering of ground water levels, and by the intrusion of sea water into pumped aquifers. Furthermore, the growth and enhancement of the economy of portions of the County have been impeded by the lack of firm water supplies. Elimination of present water resources problems and provision for indicated increased future water requirements of the County will require the development of additional water supplies. The amounts of water so required have been designated "the present and probable ultimate supplemental water requirements". As previously defined, the term "supplemental water requirement" refers to water requirement over and above the sum of safe ground water yield and safe surface water yield. Present and probable ultimate supplemental water requirements were determined both for the mean period of water supply and climate, which conditions were taken as equivalent to those occurring during the base period, and for the drought period.

Differences in mean and drought period supplemental water requirements, presented in this section, result from the effect of seasonal and cyclic climatic variations on water requirements and water supply utilization. Consideration was not given to possible utilization of developed water supplies during wet periods in excess of established safe yields.

#### Present Supplemental Water Requirements

Present supplemental water requirements were estimated for each of the hydrologic units and subunits of Ventura County by deducting the estimated safe yields of presently developed water supplies, corrected for importation and exportation, from estimated present water requirements. The present mean seasonal supplemental water requirement for the County was so determined to be about 73,000 acre-feet. It was further estimated that the present requirement for supplemental water increases during drought periods to about 89,000 acre-feet per season.

Requirements for supplemental water during periods of drought are of

particular significance in the Ventura and Santa Clara River Hydrologic Units because of the limited natural and artificial water supply regulation in portions of these units, and because of the substantial increase in water requirements therein during drought periods, particularly in the latter unit. Comparison of safe yields of developed water supplies with drought period water requirements serves to establish the magnitude of the water resources problems in these hydrologic units. In the Calleguas-Conejo Hydrologic Unit the drought period requirement for supplemental water is of lesser significance, since water resources problems therein are largely manifest in perennial lowering of ground water levels, resulting from ground water utilization in excess of mean recharge, rather than in the lack of adequate natural or artificial regulatory storage capacity.

Table 47 presents the estimated present mean and drought period seasonal supplemental water requirements in Ventura County by hydrologic units and subunits. It may be noted that in some cases values for available safe water supplies in Table 47 for the drought period exceed those presented for the mean period. This results from differences between wet and drought periods in seasonal imports of water to and exports from the several hydrologic subunits, and from the variance between wet and drought periods in water supply and disposal in ground water basins. Under "safe yield operation" of those ground water basins wherein safe yield is governed by the amount of mean seasonal replenishment, rather than by basin storage capacity or configuration or by aquifer transmissibility, increased water utilization during a drought period, with attendant reduction in replenishment, would effect a depletion of ground water storage. During ensuing wet seasons, with lesser utilization and increased replenishment, ground water levels would recover to positions prevailing at the beginning of the former drought period. Thus, over a mean period of water supply and climate there would be no net change in ground water storage, and the criterion governing safe yield in such basins would not be violated. Values presented in Table 47 under columns



headed "Net effect of modified imports and exports on safe water supply" and "Net effect of changes in remaining items of water supply and disposal on safe water supply" were derived from data and by methods and procedures presented and discussed in Chapter II.

For reasons discussed hereinafter in Chapter IV, it was assumed that the net safe yield of water developed by Matilija Reservoir, in the estimated amount of about 1,400 acre-feet per season, would be entirely utilized in the Ojai Subunit.

TABLE 47

ESTIMATED PRESENT MEAN AND DROUGHT PERIOD SEASONAL SUPPLEMENTAL WATER REQUIREMENTS  
IN HYDROLOGIC UNITS OF VENTURA COUNTY

(In acre-feet)

Hydrologic unit and subunit	Mean					Drought period				
	Water requirement	Safe yield	Net effect of imports and exports on safe water supply	Available water supply	Supplemental water requirement	Safe yield	Net effect of imports and exports on safe water supply	Available water supply	Supplemental water requirement	Net effect of changes in remain- ing items of water supply and disposal on safe water supply
Ventura	400	400	0	400	0	400	0	400	0	0
Upper Ojai	3,500	1,500	1,400	2,900	600	3,500	1,500	2,900	700	0
Upper Ventura River }	8,900	7,400	-1,500	5,900	3,000	9,000	7,400	5,900	3,100	0
Lower Ventura River }	500	100	100	200	300	500	100	200	300	0
Rincon										
Subtotals	13,300	9,400	0	9,400	3,900	13,500	9,400	9,400	4,100	0
Santa Clara River	300	0	300	300	0	300	0	300	0	0
Eastern	7,200	11,100	-3,900	7,200	0	7,600	11,100	7,600	0	0
Piru	14,300	10,000	4,300	14,300	0	15,200	10,000	15,200	0	0
Fillmore	15,700	15,600	100	15,700	0	16,800	15,600	16,800	0	0
Santa Paula	11,500	8,800	2,700	11,500	0	14,900	8,800	14,900	0	0
Mound										
Oxnard Forebay }	83,800	26,700	-2,500	24,200	59,600	97,300	26,700	23,100	74,200	0
Oxnard Plain }										
Pleasant Valley }										
Subtotals	132,800	72,200	1,000	73,200	59,600	152,100	72,200	77,900	74,200	0
Calleguas-Conejo	9,700	6,100	0	6,100	3,600	10,700	6,100	6,600	4,100	0
Simi	16,900	10,800	1,100	11,900	5,000	20,200	10,800	14,500	5,700	0
East Las Posas }										
West Las Posas }										
Conejo	2,600	2,600	0	2,600	0	3,200	2,600	3,200	0	0
Tierra Rejada }										
Santa Rosa }	3,600	3,100	0	3,100	500	4,700	3,100	4,200	500	0
Subtotals	32,800	22,600	1,100	23,700	9,100	38,800	22,600	28,500	10,300	0
Malibu	800	800	0	800	0	900	800	900	0	0
TOTALS	179,700	105,000	2,100	107,100	72,600	205,300	105,000	116,700	88,600	0

## Probable Ultimate Supplemental Water Requirements

The probable ultimate mean and drought period seasonal supplemental water requirements in Ventura County were derived by comparison of probable ultimate water requirements and safe yields, and were estimated to be about 266,000 and 287,000 acre-feet, respectively. In the derivation, consideration was given to the effects of probable future increased use of the major ground water basins on previously estimated values for presently developed safe yield.

Table 48 summarizes, by hydrologic units and subunits, the estimated ultimate supplemental water requirements for mean and drought periods. The supplemental requirements presented in Table 48 are for probable ultimate areas requiring intensive water service. It was assumed that supplemental water would not be required to meet requirements of previously discussed minor water service areas throughout the County. A brief discussion of methods and assumptions employed in deriving the ultimate supplemental requirements follows:

Ventura Hydrologic Unit. It was concluded that in the Ventura Hydrologic Unit, without construction of additional regulatory works, the yield of present sources of water supply would be no greater with the probable ultimate pattern of land use and attendant water requirements than under present conditions. It was assumed, however, that ultimately the effective storage capacity of Matilija Reservoir would be entirely lost through siltation, thereby reducing the safe yield of the presently developed water supply in the Ventura Hydrologic Unit, estimated to be 9,400 acre-feet per season, to about 8,000 acre-feet per season. Probable ultimate supplemental water requirements were derived using this latter value.

Santa Clara River Hydrologic Unit. In the Santa Clara River Hydrologic Unit, consideration was given to the effect of increased development in that portion of the Santa Clara River watershed designated Eastern Basin, and included within Los Angeles County, on flow in Santa Clara River at the county line. Land



classification surveys, conducted in connection with the preparation of State Water Resources Board Bulletin No. 2, indicated that there are about 38,000 acres of land susceptible to water-using developments in this area, as compared to present water service area of about 10,000 acres. The ultimate mean seasonal water requirement was estimated to be in excess of 60,000 acre-feet, as compared to a present water requirement of about 18,000 acre-feet. Although with data at hand it was not possible to evaluate with any degree of accuracy the effect of this probable increase in development on inflow to Ventura County, for purpose of analysis it was assumed that ultimately effluent discharge at the lower limit of Eastern Basin would be entirely eliminated. The amount of this discharge was estimated to average about 15,000 acre-feet per season over the base period, with the present pattern of land use and water supply development in Eastern Basin. This assumption may be somewhat severe with respect to the reduction in the ultimate water supply of Ventura County, since it is probable that with increased use of ground water storage in Eastern Basin effluent discharge would not be entirely eliminated. Furthermore, such increased use also would effect a reduction in flood flow in Santa Clara River at the county line, a large portion of which presently wastes to the ocean. In this regard, it was assumed that a forecast increased water requirement of 100 acre-feet per season in the portion of Eastern Basin within Ventura County would be satisfied from surface or ground water supplies in Los Angeles County, tending to increase the safe water supply available to Ventura County by that amount. In addition, it was assumed that lands in the Piru Subunit now being supplied both by effluent discharge from Eastern Basin and by import from Los Angeles County would ultimately be entirely supplied by import from Los Angeles County. Under this assumption, the ultimate mean seasonal import to the Piru Subunit would be increased by about 500 acre-feet over that estimated for the present, and would average about 2,300 acre-feet.

Monthly studies of water supply and disposal were made for Piru, Fillmore,

and Santa Paula Basins over the base period, with the probable ultimate pattern of land use prevailing therein and with the foregoing assumed changes in water supply. With exception of forecast changes in land use, water requirements, and water supply, methods and assumptions employed in the studies were identical with those used in the analysis for present conditions of development, as described in Chapter II. In commencing the studies, Piru, Fillmore, and Santa Paula Basins were assumed to be full in the spring of 1944. By the fall of 1951, it was estimated that ground water storage depletion in Piru Basin would be about 140,000 acre-feet, as compared to an actual depletion in the fall of 1951 of about 94,000 acre-feet; that ground water storage in Fillmore Basin would be depleted by about 88,000 acre-feet, as compared to an actual depletion of about 61,000 acre-feet; and that ground water storage depletion in Santa Paula Basin would be about 70,000 acre-feet, as compared to an actual depletion of about 22,500 acre-feet. Assuming a ground water storage depletion in each of these three basins in the fall of 1936 equal to that which was estimated would occur in the fall of 1951 under ultimate conditions, it was found that Piru Basin would be first filled in the spring of 1941, and that Fillmore and Santa Paula Basins would be filled by the spring of 1937. It was therefore concluded that, under the assumptions of the study, there would be no ultimate requirement for supplemental water in either the Piru, Fillmore, or Santa Paula Subunits.

It was estimated that greater use of Piru, Fillmore, and Santa Paula Basins under ultimate conditions would effect an increase in mean seasonal safe yield of these subunits by about 15,500 acre-feet over the present safe yield. Conversely it was estimated that with a further lowering of ground water levels in Santa Paula Basin there would be reduction in both effluent discharge and subsurface outflow therefrom to Oxnard Forebay Basin, thereby reducing the estimated present mean seasonal safe yield of the latter basin by about 4,300 acre-feet. Thus, the ultimate net increase in safe water supply of the Santa Clara River

Hydrologic Unit was estimated to be about 11,800 acre-feet per season, including the assumed increased import to the Eastern and Piru Subunits in the amount of 600 acre-feet per season.

The safe yield of water supplies available to meet requirements under ultimate conditions of development in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits would reflect the estimated 4,300 acre-foot per season reduction in safe yield of Oxnard Forebay Basin. Accordingly, it was estimated that this ultimate safe supply would be about 18,800 acre-feet per season during drought periods and about 19,900 acre-feet per season during mean periods.

Although it appears that underflow from Santa Paula Basin to Mound Basin would be reduced under estimated ultimate conditions, the magnitude of the probable reduction could not be evaluated with information at hand, and the safe yield of presently developed water supplies of the Mound Subunit was assumed to remain constant ultimately.

Calleguas-Conejo and Malibu Hydrologic Units. It was concluded that the ground water basins in the Calleguas-Conejo and Malibu Hydrologic Units are presently being utilized to the maximum practicable extent, and that any increased utilization thereof would either result in the establishment of overdraft or would increase existing overdrafts. Ultimate supplemental water requirements, therefore, were estimated by comparison of probable ultimate water requirements with safe yields of presently developed water supplies.



TABLE 48

ESTIMATED PROBABLE ULTIMATE MEAN AND DROUGHT PERIOD SEASONAL SUPPLEMENTAL WATER REQUIREMENTS  
IN HYDROLOGIC UNITS OF VENTURA COUNTY

(In acre-feet)

Hydrologic unit and subunit	Mean				Drought period			
	Water requirement	Safe yield	Net effect and safe water supply	Available: water requirement	Net effect of imports and exports on safe water supply	Net effect of changes in remain- ing items of water supply and disposal on safe water supply	Available: water requirement	
Ventura								
Upper Ojai	3,700	400	0	4,000	0	0	3,600	
Ojai	5,800	1,500	0	6,000	0	0	4,500	
Upper Ventura River	24,000	6,000	-100	24,200	-100	0	18,300	
Lower Ventura River	5,000	100	100	5,000	100	0	4,800	
Rincon								
Subtotals	38,500	8,000	0	39,200	0	0	31,200	
Santa Clara River								
Eastern	400	0	400	400	0	0	0	
Piru	11,300	14,700	-3,400	11,400	-2,900	-400	0	
Fillmore	20,700	16,400	4,300	22,000	3,300	2,300	0	
Santa Paula	21,200	21,100	100	22,800	1,300	400	0	
Mound	26,900	8,800	2,700	27,700	3,100	3,000	12,800	
Oxnard Forebay	146,900	22,400	-2,500	160,900	-3,600	0	142,100	
Oxnard Plain								
Pleasant Valley								
Subtotals	227,400	83,400	1,600	245,200	1,600	5,300	154,900	
Calleguas-Conejo								
Simi	20,100	6,100	0	20,800	0	500	14,200	
East Las Posas	49,500	10,900	1,100	56,800	1,600	2,100	42,300	
West Las Posas	26,600	2,600	0	28,300	0	600	25,100	
Conejo	8,100	3,100	0	10,200	0	1,100	6,000	
Tierra Rejada								
Santa Rosa								
Subtotals	104,300	22,600	1,100	116,100	1,600	4,300	87,600	
Malibu	13,700	800	0	14,100	0	100	13,200	
TOTALS	383,900	114,800	2,700	414,600	3,200	9,700	286,900	

#### CHAPTER IV. PLANS FOR WATER SUPPLY DEVELOPMENT

It has been shown that current water resources problems in Ventura County include perennial and progressive lowering of water levels in certain ground water basins of the Calleguas-Conejo Hydrologic Unit, overdraft on ground water supplies in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins of the Santa Clara River Hydrologic Unit, resulting in the intrusion of sea water to pumped aquifers during periods of drought, and the utilization of both surface and ground water supplies in the Ventura Hydrologic Unit in excess of estimated safe yields. It has also been shown that there is an estimated mean seasonal requirement for supplemental water in the County of about 73,000 acre-feet at the present time. It has been further shown that elimination of present water resources problems, together with provision for anticipated future growth of the County, will ultimately require the development of supplemental water in the estimated mean seasonal amount of about 266,000 acre-feet.

Sources of supplemental water are available locally in the portion of runoff from watersheds of the Ventura and Santa Clara Rivers that presently wastes to the ocean, which portion would have averaged an estimated 230,000 acre-feet per season over the base period with the present pattern of land use and water supply development. Utilization of this presently wasted water will require the development of equalizing storage capacity either in ground water basins or in surface reservoirs, and construction of facilities to equitably distribute the water so conserved to areas of need. Studies described in this chapter indicate that, because of the erratic nature of the occurrence of runoff in Ventura and Santa Clara Rivers, in excess of 1,500,000 acre-feet of storage capacity would be required to effect complete salvage of this surface waste. Furthermore, because of the relatively high cost of developing surface storage capacity, together with a general paucity of feasible dam and reservoir sites, it is indicated that presently undeveloped ground water storage capacity should

be exploited to the maximum practicable extent. It is concluded that under the limitations imposed by economic feasibility, insufficient local water could be conserved and equitably distributed to satisfy present supplemental requirements, and that final solution of the water resources problems of Ventura County must lie in importation of water from outside sources.

As was stated in Chapter I, the Division of Water Resources is presently conducting surveys and studies for the State-Wide Water Resources Investigation, under direction of the State Water Resources Board. This investigation has as its objective the formulation of The California Water Plan for full conservation, control, and utilization of the State's water resources, to meet present and future water needs for all beneficial purposes and uses in all parts of the State, insofar as practicable. Although the investigation is still in progress, it is sufficiently advanced to permit tentative description of certain major features of The California Water Plan which would provide supplemental water to meet the probable ultimate requirements of Ventura County. These projects, which are described in general terms in this chapter under the section entitled "Plans for Importation by Means of Feather River Project", would also provide supplemental water supplies for other water deficient areas of California. In addition, benefits from the projects would include hydroelectric power, flood and salinity control, mining debris storage, and incidental benefits in the interest of recreation and preservation of fish and wildlife.

In general, the major features of The California Water Plan which were mentioned in the preceding paragraph would be large multipurpose projects requiring relatively large capital expenditures. Additional study will be required to estimate final costs and to determine possible means of financing these major projects. Plans presented in this bulletin for the further development of local supplies are those under consideration for current financing,



construction, and operation by appropriate local public agencies. The proposed local developments would be such that the works could be integrated into the foregoing major features of The California Water Plan.

Descriptions of various plans considered for the conservation and utilization of local water supplies in Ventura County, and of plans for importing water from available sources outside the County, are presented in this chapter, under section headings designated "Plans for Local Conservation Development", "Plans for Importation by Means of Feather River Project", "Plans for Importation by Means of Metropolitan Water District of Southern California", and "Discussion of Alternative Initial Plans for Water Supply Development". Included therein are estimates of costs of the various plans, estimates of the amounts of supplemental water that would be made available by their adoption and construction, and an evaluation of the plans from the standpoint of economic and financial feasibility.

Design of features of plans presented herein was necessarily of a preliminary nature and primarily for cost estimating purposes. More detailed investigation, which would be required in order to prepare construction plans and specifications, might result in designs differing in detail from those presented in this bulletin. However, it is believed that such changes would not result in significant modifications in estimated costs. The capital costs of dams, reservoirs, diversion works, conduits, pumping plants, and appurtenances included in the considered conservation, conveyance, and distribution systems were estimated from preliminary designs based largely on data from surveys made during the current investigation, both by the Division of Water Resources and other cooperating agencies. Approximate construction quantities were estimated

from these preliminary designs. Unit prices of construction items were determined from recent bid data on projects similar to those in consideration, or from manufacturers' cost lists, and are considered representative of prices prevailing in the spring of 1953. Estimates of capital costs included costs of rights of way and construction, plus 10 per cent for engineering and 15 per cent of the construction costs for contingencies, and interest during one-half of the estimated construction period at 4 per cent per annum. Estimates of annual costs included interest on the capital investment at 4 per cent, amortization over a 40-year period on a 4 per cent sinking fund basis, replacement, operation and maintenance costs, and costs of electrical energy required for pumping.

#### Plans for Local Conservation Development

Consideration was given to enhancement of the presently developed yields of local water supplies, both through construction of equalizing storage capacity in surface reservoirs and in ground water storage. From the results of reconnaissance examination of many possible dam and reservoir sites throughout the County, it was concluded that detailed consideration should be given to ten of the more favorable sites, located in the Ventura and Santa Clara River watersheds. In connection with the studies of further conservation of local water supplies, consideration was given to transfer of surplus water between hydrologic units.

Planned operation of certain ground water basins of the County, either by their greater utilization or by changes in present pumping patterns, or both, would increase their utility by providing additional usable storage capacity for water supply regulation. The Ojai, Piru, Fillmore, Santa Paula, and Oxnard Forebay Basins were studied in this regard. In addition, the Simi and East and West Las Posas Basins were studied from the standpoint of providing regulation for potential imported supplies. Certain legal considerations regarding the

vested rights of overlying users must be recognized in such planned operation of ground water storage.

As has been stated, water susceptible to capture by the construction of surface reservoirs in Ventura County, or by further development of ground water storage, is that which would waste to the ocean over a mean period of water supply and climate with the present pattern of land use and water supply development. Estimates were made, therefore, of the portion of this waste occurring during the base period which originated in the Ventura and Santa Clara Rivers and in each of the major tributaries of these rivers. The results of these estimates are presented in Table 49.

It should be pointed out that values presented in Table 49 for the Santa Clara River were derived under the assumption that Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins would be operated in accordance with their safe yield. Since records of surface outflow in the Santa Clara River during the base period are not available prior to the season of 1947-48, the values presented in Table 49 are based entirely on estimates, evaluated by methods and procedures described in Chapter II, and because of the nature of the studies are only indicative of magnitude. Seasonal amounts of waste to the ocean from the Santa Clara River system originating in each of the indicated major tributaries were determined from analysis of the monthly hydrologic studies presented in Chapter II.

Values presented for waste to the ocean from the Ventura River were determined by correcting measured amounts of runoff at the gaging station near Ventura for impairment by Matilija Reservoir prior to 1948, and for differences in actual historical diversion by the City of Ventura from the estimated present seasonal diversion and pumping requirement of that City. It was assumed that any other differences in the land use pattern and attendant use of water in the remainder of the Ventura River drainage area during the base period from that estimated for



the present were negligible and would not affect measured runoff at the foregoing station. It was assumed that the measured runoff of Coyote Creek near Ventura represented the waste to the ocean from that stream during the base period. Estimates were made of the present impairment to the full natural runoff of both Matilija and North Fork of Matilija Creeks, to determine the portion of the previously estimated waste from the entire Ventura River system originating therein. Waste from the remainder of the Ventura River system, shown in Table 49, was then determined as a differential.

TABLE 49

ESTIMATED SEASONAL WASTE TO THE OCEAN FROM  
VENTURA AND SANTA CLARA RIVERS DURING BASE PERIOD,  
WITH PRESENT PATTERN OF LAND USE AND WATER SUPPLY DEVELOPMENT  
(In acre-feet)

Season	Ventura River near Ventura					Santa Clara River at mouth										Total,	
	Coyote Creek	North Fork Matilija Creek	Matilija Creek	Matilija Creek	Miscel- laneous runoff	Subtotal, Ventura River	Santa Clara River above County line	Piru Creek	Sepe Creek	Paula Creek	Miscel- laneous runoff	Subtotal, Santa Clara River	Santa Clara River	Santa Clara River	Santa Clara River	Santa Clara River	Santa Clara River
1936-37	22,300	12,200	36,400	27,000	56,300	97,900	4,100	18,300	91,800	19,000	27,000	160,200	258,100				
1937-38	26,600	21,700	73,000	65,300	7,000	186,600	36,800	88,000	217,000	38,000	84,700	464,700	651,300				
1938-39	3,000	1,500	5,400	7,400		17,300	10,800	16,000	28,500	4,200	6,600	66,100	83,400				
1939-40	2,400	700	1,500	4,300		8,900	2,800	5,600	14,100	1,800	2,700	27,000	35,900				
1940-41	50,900	30,200	115,900	56,300		253,300	70,900	204,000	370,600	55,200	101,700	802,400	1,055,700				
1941-42	3,600	2,600	5,900	7,000		19,100	27,500	20,500	28,700	4,900	5,800	87,400	106,500				
1942-43	28,900	14,800	51,100	39,200		134,000	62,400	88,500	163,800	36,100	79,900	430,700	564,700				
1943-44	15,200	8,600	29,500	19,200		72,500	67,500	99,500	125,100	18,800	42,500	353,400	425,900				
1944-45	7,300	3,200	7,300	10,400		28,200	10,800	16,300	36,200	7,000	7,300	77,600	105,800				
1945-46	3,600	3,700	10,300	4,000		21,600	6,400	12,400	37,100	5,900	8,800	70,600	92,200				
1946-47	2,800	1,400	3,000	2,600		9,800	7,500	9,700	25,100	3,900	7,300	53,500	63,300				
1947-48	0	0	0	0		0	0	0	0	0	0	0	0				
1948-49	0	0	0	0		0	0	0	0	0	0	0	0				
1949-50	1,500	0	0	900		2,400	0	0	0	0	0	0	2,400				
1950-51	0	0	0	0		0	0	0	0	0	0	0	0				
Average for base period, 1936-37 through 1950-51	11,200	6,700	22,600	16,300		56,800	20,500	38,600	75,900	13,000	24,900	172,900	229,700				
Average for wet period, 1936-37 through 1943-44	19,100	11,500	39,900	28,200		98,700	35,400	67,500	130,000	22,300	43,800	299,000	397,700				
Average for drought period, 1944-45 through 1950-51	2,200	1,200	2,900	2,500		8,800	3,500	5,500	14,100	2,400	3,300	28,800	37,600				

Examination of Table 49 will show that the estimated mean seasonal waste to the ocean from the Ventura and Santa Clara Rivers under the present pattern of land use and water supply development is about 230,000 acre-feet. It is also indicated that during a drought period the average waste would be about 38,000 acre-feet per season, or about 16-1/2 per cent of the mean. During the wet period, the waste would average about 400,000 acre-feet per season, which amount approaches twice the mean, and is over ten times greater than the average amount for the drought period. Thus, it is evident that the effective conservation of local supplies requires development of carry-over storage capacity to reduce waste to the ocean during wet periods and make it available for beneficial use during periods of drought.

#### Potential Surface Storage Developments

Investigation of potential surface storage developments in Ventura County included hydrologic studies to ascertain the amounts of supplemental water that could be developed by construction of reservoirs, with various storage capacities at the several sites considered, geologic investigations to determine the suitability of dam sites as to type and height of dam, and estimates of capital and annual costs in order to establish economic relationships between various reservoir storage capacities at a given site and between the several sites. After preliminary reconnaissance, efforts were concentrated on more detailed investigation of the Casitas dam and reservoir site on Coyote Creek, a tributary of the Ventura River; the Ferndale site on Santa Paula Creek; the Cold Spring, Topatopa, Hammel, and Fillmore sites on Sespe Creek; and the Upper Blue Point, Blue Point, Devil Canyon, and Santa Felicia sites on Piru Creek. The locations of these dam and reservoir sites are shown on Plate 25, entitled "Potential Local Water Storage Developments and Conveyance Units for Importation of Water to Ventura County".



Reconnaissance investigation of potential dam and reservoir sites in the Calleguas-Conejo Hydrologic Unit, together with hydrologic studies, indicated that there are few feasible sites, and that present waste of water from Calleguas and Conejo Creeks is insignificant in comparison with present and probable future supplemental water requirements in the unit. Therefore, no further consideration was given to additional surface regulation and conservation of water supplies of these streams.

Estimates were made of monthly runoff during the base period at each of the ten dam sites given detailed consideration. Estimates were also made of mean seasonal waste to the ocean of runoff originating above each of the sites under the present pattern of land use and water supply development. For various selected reservoir storage capacities at each site, monthly operation studies were made, utilizing the aforementioned monthly estimates of runoff for the base period, in order to determine relationships between storage capacity and yield. Monthly values for reservoir evaporation were estimated from available records of evaporation in Los Angeles and Santa Barbara Counties. Net safe seasonal yields that would be developed with construction of the considered reservoir storage capacities were determined by deducting, from yields derived from the operation studies, the amounts of water that would have been put to beneficial use by downstream surface and ground water users without construction of the reservoir.

In operation studies for the proposed Casitas Reservoir, in the Ventura Hydrologic Unit, monthly percentages of seasonal reservoir draft were taken as equal to the estimated average monthly distribution of the seasonal demand for water of the City of Ventura, as shown in the following tabulation:

<u>Month</u>	<u>Per cent of seasonal reservoir draft</u>	<u>Month</u>	<u>Per cent of seasonal reservoir draft</u>
October	9	April	8
November	7	May	9
December	7	June	10
January	6	July	11
February	6	August	11
March	7	September	9

It was demonstrated in Chapters II and III that water problems in the Santa Clara River Hydrologic Unit are manifest in overdraft on ground water supplies on the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, and that in the future ground water overdraft probably will prevail in the Mound Subunit. It was also demonstrated that neither at the present time nor under assumed probable ultimate conditions of development would supplemental water be required in the Piru, Fillmore, or Santa Paula Subunits. Thus, salvage of water presently wasting to the ocean in the Santa Clara River would be for the primary purpose of alleviating ground water overdraft in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, and the measure of reservoir benefit would be the amount of new water that would be made available for beneficial use in these subunits.

The new water that would be developed by construction of reservoirs on tributaries of the Santa Clara River was determined from two operating criteria: (1) operation of the reservoirs on the basis of uniform seasonal releases to the Oxnard Plain, Oxnard Forebay, and Pleasant Valley Subunits, hereinafter termed the "uniform release" method, and (2) operation of the reservoirs on the basis of rapid releases to ground water storage in the Oxnard Forebay Basin, hereinafter termed the "rapid release" method.

Under uniform release operation, it was assumed that water stored in surface reservoirs would be released in equal seasonal amounts at monthly rates corresponding to the estimated average monthly percentages of seasonal demand

for water in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits during a drought period. These monthly percentages are presented in the following tabulation:

<u>Month</u>	<u>Per cent of seasonal reservoir draft</u>	<u>Month</u>	<u>Per cent of seasonal reservoir draft</u>
October	10	April	7
November	8	May	10
December	6	June	11
January	5	July	11
February	4	August	12
March	4	September	12

With such uniform release operation, lands on the coastal plain requiring supplemental water would be supplied directly from the reservoirs. Analysis indicated that, because there are from 12 to 27 miles of pervious stream channel between the proposed reservoirs and the Oxnard Forebay Basin, transmission losses would be prohibitive unless the stored water were conveyed to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits in a conduit.

In the uniform release operation studies, releases were also made from reservoir storage to satisfy prior rights of downstream surface and ground water users. Sufficient water was so released to maintain ground water levels in Piru, Fillmore, and Santa Paula Basins in the fall of 1951 equal to those which would have prevailed without the reservoirs and with the present pattern of land use and water supply development.

It was found that the maximum rate of extraction of water that could be maintained from each of the reservoirs was governed by the period of drought from 1944-45 through 1950-51. The net safe seasonal yield of a reservoir was taken as equal to this determined maximum seasonal extraction, less the average



seasonal reduction in water supplies otherwise available for beneficial use in Oxnard Forebay Basin resulting from operation of the reservoir. It was found that a substantial increase in new water would be realized in Oxnard Forebay Basin were the aforementioned releases for prior rights in Piru, Fillmore, and Santa Paula Basins not made, thereby causing ground water levels in these three basins to experience greater lowering than would have occurred during the base period with the present pattern of land use and water supply development.

Under the "rapid release" method of reservoir operation, it was assumed that demands for supplemental water on the coastal plain would be met from Oxnard Forebay Basin, and that the proposed surface storage developments would be largely utilized for temporary detention of flood waters for their subsequent rapid release to this basin. In the operation studies, releases were made from the reservoirs after cessation of heavy winter flow in the Santa Clara River, and when sufficient ground storage capacity was available for percolation of the released water in Oxnard Forebay Basin. It was assumed that the released water would be conveyed to Oxnard Forebay Basin in natural channels of the Santa Clara River and its tributaries. A conduit for this purpose was considered infeasible, because of the prohibitive cost of providing sufficient conduit capacity to accomplish the required rapid reservoir depletion. The rates of release were large enough to minimize percolation and other losses in ground water basins upstream from Oxnard Forebay Basin, but the maximum rates were limited by the amount of flow which could be percolated in Oxnard Forebay Basin. Water was not released from the reservoirs when there was sufficient flow in the Santa Clara River to satisfy percolation demands in Oxnard Forebay Basin or when ground water storage in the basin was filled. It was attempted to deplete the surface reservoir storage each season, so that the maximum storage space would be available for capture of flood waters in the ensuing winter months.

Under this rapid release method of operation, the net safe seasonal yield of the proposed reservoirs was taken as the average seasonal increase in

water made available for beneficial use in the Santa Clara River system during the drought period. This new water would be comprised of the net salvage of surface waste during the period, plus water held over from the wet period in surface storage, less reservoir evaporation loss. However, since present and probable future water problems in the Santa Clara River Hydrologic Unit are considered to prevail in the coastal plain only, any of the salvaged water retained in ground water storage upstream from Oxnard Forebay Basin should not be considered as a manifestation of reservoir benefit. As has been stated, the measure of benefit from proposed surface reservoirs is the amount of new water made available for beneficial use during a period of drought in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits. The effect of replenishing the upper ground water basins with salvaged water would be to reduce their utility as natural regulators of Santa Clara River water.

It was found that during the drought period reduction in waste to the ocean effected by the proposed surface reservoirs was about the same under either of the two methods of operation. However, the amount of new water made available at Oxnard Forebay Basin during the drought period was found to be substantially greater when a reservoir was operated by the uniform release method and the released water was conveyed to the coastal plan in a conduit.

Selected combinations of surface reservoirs of varying capacities at certain of the more favorable sites were operated coordinately under each of the two foregoing operational methods. Because of the effects of reservoir operation on downstream ground water supplies, the total yield developed by two reservoirs operated coordinately would be less, in some cases, than the summation of the yields of the two if operated alone.

It should be pointed out that the net safe yield of a reservoir operated under either of the two foregoing criteria could exceed the estimated mean seasonal waste to the ocean of water originating above the reservoir site.

By withholding runoff in surface storage, greater amounts of other waters in the system would have an opportunity to percolate to ground water storage than is presently the case. The demand on stored water to maintain ground water levels that would have prevailed without the reservoir construction would be accordingly reduced.

As has been stated, net safe yields of potential surface reservoirs in Ventura County were determined from water supply data for the base period from 1936-37 through 1950-51, and the magnitudes of yields so determined were governed by the critical drought period from 1944-45 through 1950-51. It is known that the period governing safe draft that can be maintained indefinitely from a reservoir is dependent on relationships between its storage capacity and the magnitude and regimen of flow of the particular stream. For any given stream, the critical period of water supply may change for different considered reservoir storage capacities. In general, for reservoir storage capacities considered in this bulletin, the drought period from 1944-45 through 1950-51 did govern the magnitude of safe yield. However, exceptions occurred in several of the larger reservoir capacities studied, particularly as storage capacities approached magnitudes required to completely control a given stream over the base period. For such larger capacities, it was estimated that the critical water supply periods that occurred either from 1922-23 through 1935-36 or from 1917-18 through 1935-36 would usually govern safe yields. In such instances, appropriate qualification of the values of safe yield presented herein has been made. It should be emphasized again, however, that reliable records of surface runoff in Ventura County are not available for seasons prior to 1927-28, and that runoff estimates are necessarily based either on rainfall-runoff relationships or correlations with runoff of streams in Santa Barbara or Los Angeles Counties. Furthermore, at only a few of the dam sites under consideration are there stream gaging stations of such proximity thereto, that reliable estimates of runoff during the base period could be made.



For each of the proposed surface reservoirs in Ventura County, consideration was given to future losses of effective storage capacity through sedimentation. The problem of reservoir sedimentation is of great significance in the County, and in comparable areas of southern California, because of the large bed loads carried by flood waters. Over a long period of years, the effective capacity of any reservoir will be destroyed through accumulation of sediment. The elapsed time prior to such complete loss of reservoir utility is dependent upon storage capacity of the development, and upon characteristics of the particular drainage area under consideration, such as soil type, vegetative cover, and nature and occurrence of runoff from the watershed. Brush and forest fires in a watershed reduce resistance to erosion and tend to increase sedimentation problems. Values for average seasonal rates of sedimentation utilized in this bulletin were obtained from reports by Harold Conkling, Consulting Engineer, entitled "Demand on Casitas Reservoir and Safe Yield", dated April, 1950, and "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District", dated September, 1949. The estimates in Mr. Conkling's reports were obtained from "Flood Frequencies and Sedimentation from Forest Watersheds", by Henry W. Anderson, California Forest and Range Experiment Station, United States Forest Service, Berkeley, California, dated February, 1949. For the proposed Casitas Reservoir on Coyote Creek, an average unit seasonal sediment production of 2.3 acre-feet per square mile of drainage area above the site was estimated. For watersheds of Sespe and Piru Creek, estimated seasonal values of 2.4 acre-feet per square mile and 1.6 acre-feet per square mile, respectively, were employed. The average unit seasonal sediment production of Santa Paula Creek was taken equal to that of Sespe Creek. Yields for all reservoirs considered in this bulletin were estimated on the basis of effective capacities that would remain after 20 years of operation. The constructed capacity of proposed reservoirs is hereinafter referred to as the

"gross reservoir storage capacity", and the effective capacity remaining after 20 years of operation is referred to as the "net reservoir storage capacity".

Spillways for proposed dams and reservoirs in Ventura County were designed to pass the probable peak discharge from a flood having a frequency of once in one thousand years. Because of the preliminary nature of the designs, no consideration was given to the effect of surcharge storage in the reservoirs on reducing estimated peak flows over the spillways.

Because of the erratic nature of occurrence of runoff in streams of Ventura County, there might be a considerable lapse of time subsequent to construction of reservoirs before they would be filled and in effective operation. A large reservoir constructed at the beginning of the critical water supply period from 1922-23 through 1935-36 might have required as long as 20 years to fill. On the other hand, a reservoir constructed immediately prior to the wet period from 1936-37 through 1943-44 would have filled in a considerably shorter length of time. As has been stated, for over three years subsequent to its construction, in 1948, Matilija Reservoir was virtually dry. Runoff occurring during the one month of January, 1952, filled this reservoir. As an aid in selection of desirable reservoir capacities to be constructed at certain sites appearing favorable in other respects, operation studies were made for the period from 1894-95 through 1950-51, for which period only rough estimates of seasonal runoff in Ventura County streams are available, to determine the probable average number of years that would elapse prior to filling the reservoirs with various capacities.

The following sections describe in some detail the results of investigation of each of the ten considered dam and reservoir sites in Ventura County. Certain of these results are depicted graphically on Plate 35, entitled "Relationship between Storage Capacity of Reservoirs and Capital Cost"; Plate 36, entitled "Relationship between Storage Capacity of Reservoirs and Net Safe

Seasonal Yield "; Plate 37, entitled "Relationship between Net Safe Seasonal Yield of Reservoirs and Annual Unit Cost; and Plate 38, entitled "Probable Time Required to Fill Reservoirs after Construction." Yields for reservoirs on tributaries of the Santa Clara River utilized in preparing Plates 36 and 37 were those determined from the uniform release method of operation, with releases for maintenance of ground water levels in Piru, Fillmore and Santa Paula Basins. Costs employed in preparing Plate 37, however, do not include the cost of a conduit that would be necessary to realize the indicated yields, and are, therefore, indicative of the annual cost per acre-foot of new water at the reservoirs.



Casitas Dam and Reservoir. The Casitas dam site is located on Coyote Creek, about 2.5 miles above its confluence with the Ventura River and about 0.7 mile downstream from State Highway 150. A county road, the Casitas Pass Road, passes along the right abutment of the site, and joins State Highway 150 about one mile upstream. Both the dam site and reservoir area are within a former land grant, designated Rancho Santa Ana. The stream bed elevation at the dam site is about 325 feet, U.S.G.S. datum. Construction of a dam and reservoir at this site would permit conservation of flood waters of Coyote Creek, and of the Ventura River diverted to the reservoir, and would be for the primary purpose of providing supplemental water to the Ventura Hydrologic Unit. Consideration was also given to conveyance of water from the reservoir to the Santa Clara River Hydrologic Unit.

The drainage area of Coyote Creek above the Casitas dam site comprises about 36 square miles, and produced an estimated average seasonal runoff of about 10,100 acre-feet during the base period. Under the plans considered, inflow to a reservoir at the Casitas site would be augmented by diversion of surplus waters from the Ventura River. Seasonal runoff at the considered diversion site would have averaged an estimated 33,500 acre-feet during the base period had Matilija Reservoir been in operation, from a drainage area of about 75 square miles.

Other Dam and Reservoir Sites Considered. Reconnaissance examinations were made of three other dam and reservoir sites in the Ventura River drainage area during the course of the investigation. The dam sites were located, respectively, on the Ventura River a short distance below the confluence of North Fork of Matilija Creek and Matilija Creek, designated the Nordhoff site; on the main thread of the Ventura River upstream from Foster Park and below the mouth of San Antonio Creek, designated the Arnaz site; and on San Antonio Creek immediately above its confluence with Ventura River, designated the San Antonio

site. Although it was indicated that the two sites on the main thread of the river had certain advantages over the Casitas site, in that direct capture of the greatest portion of runoff of the Ventura River could be effected, probable costs of construction of dams at these sites were considered prohibitive. A dam at the Arnaz site would necessitate relocation of a branch of the Southern Pacific Railroad and a portion of U. S. Highway 399, and in addition would require the acquisition of several hundred acres of suburban residences in the reservoir area. Construction of a dam at the Nordhoff site would also necessitate relocation of U. S. Highway 399, which in this vicinity would be an expensive undertaking, and would inundate the existing Matilija Dam. The San Antonio Creek site was given no further consideration because of the relatively minor runoff in San Antonio Creek, and because it did not compare favorably with the Casitas site for offstream storage of Ventura River water due to the limited storage capacity available.

Areas and Capacities of Reservoir. The Casitas reservoir area was mapped up to an elevation of 550 feet in March, 1951, by the Ventura County Flood Control District, at a scale of 1 inch equals 400 feet, with a 25-foot contour interval. The District also mapped the dam site in 1949, at a scale of 1 inch equals 100 feet, with a 5-foot contour interval. Storage capacities of Casitas Reservoir at various stages of water surface elevation are given in Table 50.

TABLE 50

## AREAS AND CAPACITIES OF CASITAS RESERVOIR

Depth of water at dam, in feet	: Water surface elevation, U.S.G.S. datum, in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	325	0	0
5	330	8	20
15	340	25	185
25	350	48	550
35	360	105	1,300
45	370	170	2,700
55	380	235	4,700
65	390	290	7,300
75	400	350	10,500
85	410	410	14,400
95	420	480	18,800
105	430	570	24,000
115	440	670	30,200
125	450	730	37,200
135	460	870	45,300
145	470	960	54,400
155	480	1,070	64,600
165	490	1,190	75,900
175	500	1,330	88,500
178	503	1,380	92,000
185	510	1,490	102,600
187	512	1,530	105,000
195	520	1,650	118,300
202	527	1,790	130,000
205	530	1,830	135,800
215	540	1,990	154,900
215.5	540.5	2,000	156,000
225	550	2,140	175,600

Geology of Dam Site. Geologic investigation indicated that the Casitas site is suitable for construction of an earthfill dam up to a maximum height of about 235 feet, which probably is about the upper limit from the topographic standpoint. The geology of the site was studied by George D. Louderback in 1948, by the D. R. Warren Company in 1946, and by J. B. Lippincott in 1934. During the course of the investigation, geologists from the Division of Water Resources examined the site and reviewed the prior geologic reports. Thirteen borings were made at the dam site in 1948, under the direction of Dr. Louderback, totaling about



1,310 feet of depth, of which about 924 feet comprised core borings. In addition, three tunnels totaling about 655 feet in length were driven into the right abutment. In 1946, the D. R. Warren Company drilled ten holes. During the Lippincott investigation, in 1934, six holes were drilled totaling about 366 feet in depth. In addition, exploratory trenching was done on both abutments.

The Casitas dam site is formed by a slight topographic constriction of the valley floor, where Coyote Creek has cut through resistant basal sandstone layers of Vaqueros age. These harder beds are inter-stratified with thicker, softer, shaly beds. The Vaqueros formation overlies a reddish, sandy, Sespe shale containing veinlets of gypsum, and in turn is overlain by grayish colored Rincon shale. All of these formations dip from 20 to 30 degrees upstream, which is a favorable attitude, and strike generally across the channel parallel to the proposed axis. The beds are slightly fractured, and although minor faults of slight displacement occur, they are generally sound and in reasonably good condition. The easterly extension of the more resistant Vaqueros beds, along the strike line, forms a relatively narrow ridge comprising the left abutment, with the downstream or southerly slope thereof being quite steep because of comparatively recent undercutting by Coyote Creek. Appreciably wide flat terraces are present on either side of the channel in the vicinity of the axis. The westerly or right abutment does not have so pronounced a ridge, although its upper portion shows the resistant Vaqueros beds, forming a small but sharply defined cliff above their contact in a ravine with the softer underlying Sespe formation.

Both abutments are covered with a moderately heavy soil blanket estimated to be from 5 to 15 feet in thickness. A small slide or slump exists between elevations of 325 and 425 feet on the right abutment upstream from the axis. Here the more brittle Vaqueros sandstone has slumped slightly out of

position, possibly due to yielding of the less competent underlying beds. The slide comprises about 50,000 cubic yards of material. Most of this material exposed by the aforementioned tunnels appears to be reasonably firm and stable, although a final decision as to its suitability for foundation necessarily would have to await final stripping. From examination of the material exposed in cores, tunnels, and on the surface, it does not appear that the foundation area would accept much grout, unless large unknown seams or cavities are encountered during stripping operations. As the ridge forming the left abutment is rather thin, leakage from the reservoir could result unless the upstream slope was blanketed with impervious material.

Major faulting at the site was not observed or indicated by exploration work. However, it is apparent that numerous small faults and possibly shear zones exist in the foundation area. Others may come to light with additional exploratory work, particularly in the channel section. While a small amount of shaping may be necessary in the developed foundation, no serious defect is believed to exist. Since the Casitas dam site lies in a moderately seismically active area, proper consideration of this factor should be given in the design of any structure at this site.

Operation and Yield of Reservoir. As was stated, consideration was given to utilization of a reservoir at the Casitas site not only for impounding runoff in Coyote Creek but also for offstream storage of surplus waters diverted from the Ventura River. Diversion sites studied in this regard were located so as to enable capture both of flow in the North Fork of Matilija Creek and spill from Matilija Reservoir. Table 51 presents seasonal base period values of estimated runoff of Coyote Creek at the Casitas dam site, measured runoff of the North Fork of Matilija Creek, and estimated spill from Matilija Reservoir operated to give a gross seasonal yield of 3,700 acre-feet. Runoff of Coyote Creek at the Casitas dam site was estimated to be 90 per cent of measured

runoff at the U.S.G.S. stream gaging station on Coyote Creek near Ventura.

TABLE 51

SEASONAL RUNOFF OF  
COYOTE CREEK AT CASITAS DAM SITE  
AND NORTH FORK OF MATILIJA CREEK,  
AND SEASONAL SPILL FROM MATILIJA RESERVOIR,  
DURING BASE PERIOD

(In acre-feet)

Season	: Coyote Creek : at Casitas : dam site*	: North Fork of : Matilija Creek : near Matilija	: Spill from : Matilija : Reservoir*
1936-37	20,060	13,590	40,430
1937-38	23,900	22,920	77,230
1938-39	2,700	2,740	9,600
1939-40	2,190	2,250	5,300
1940-41	45,800	31,290	120,260
1941-42	3,270	4,300	9,630
1942-43	26,020	15,970	55,290
1943-44	13,670	9,870	33,650
1944-45	6,550	4,820	11,060
1945-46	3,240	5,150	14,270
1946-47	2,550	3,000	6,260
1947-48	50	760	0
1948-49	130	1,150	0
1949-50	1,320	1,630	0
1950-51	<u>90</u>	<u>590</u>	<u>0</u>
TOTALS	151,530	120,030	382,980
AVERAGES	10,100	8,000	25,530

\* Estimated.

As a first step in the analysis of Casitas reservoir, estimates were made of the amounts of water susceptible to diversion from the Ventura River with works having capacities of from 50 to 200 second-feet, in increments of 50 second-feet. By analyzing daily records of runoff in the North Fork of Matilija Creek and estimates of daily rates of spill that would have occurred from Matilija Reservoir during the base period, the amounts of water that could



have been diverted to Casitas Reservoir for each of the conduit capacities were determined. Neglecting for the moment prior rights to Ventura River water below the point of diversion to Casitas Reservoir, the water available for such diversion would have included all spills from Matilija Reservoir plus the entire runoff of the North Fork of Matilija Creek. The seasonal amounts of water that could have been so diverted to Casitas Reservoir during the base period, by the four capacities of diversion conduit and with Matilija Reservoir in operation, are presented in Table 52.

TABLE 52

ESTIMATED SEASONAL POTENTIAL FOR DIVERSION OF WATER  
FROM VENTURA RIVER TO CASITAS RESERVOIR DURING BASE PERIOD  
WITH MATILIJA RESERVOIR IN OPERATION  
AND WITHOUT PROVISION FOR DOWNSTREAM RIGHTS

(In acre-feet)

Season	: Capacity of diversion conduit, in second-feet			
	: 50	: 100	: 150	: 200
1936-37	15,920	24,960	30,890	35,000
1937-38	18,500	28,490	35,410	40,690
1938-39	10,090	11,500	12,160	12,340
1939-40	6,000	6,910	7,150	7,240
1940-41	23,700	38,790	49,780	59,150
1941-42	11,710	12,600	12,960	13,260
1942-43	14,960	23,000	28,590	32,900
1943-44	15,920	21,630	25,520	28,410
1944-45	10,370	11,550	12,100	12,500
1945-46	9,020	10,670	11,530	12,340
1946-47	6,430	7,220	7,600	7,890
1947-48	760	760	760	760
1948-49	1,150	1,150	1,150	1,150
1949-50	1,610	1,630	1,630	1,630
1950-51	<u>590</u>	<u>590</u>	<u>590</u>	<u>590</u>
TOTALS	146,730	201,450	237,820	265,850
AVERAGES	9,780	13,430	15,850	17,720

By combining estimated values of diversions of Ventura River water for each of the four conduit capacities with estimated values of runoff in Coyote Creek at the dam site, total monthly inflows to Casitas Reservoir were determined. From these estimates, mass diagrams of cumulative monthly inflow were plotted. Graphic analysis of the mass diagrams indicated the variation in reservoir yield with storage capacity for each of the four diversion capacities considered, up to the maximum capacity of Casitas Reservoir required to regulate each of the diversions.

Yields indicated on the mass diagrams were corrected to take into account evaporation losses. This was done making operation studies of the selected reservoirs on a monthly basis throughout the base period. An estimated average depth of net seasonal evaporation of 2.00 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies:

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.20	April	0.15
November	0.09	May	0.20
December	0.05	June	0.25
January	0.04	July	0.28
February	0.05	August	0.30
March	0.11	September	<u>0.28</u>
		TOTAL	2.00

By the same method yields from the mass diagrams were further reduced by the amounts of rights to water of users downstream from the diversion point on the Ventura River. These rights were estimated as the reduction resulting from the diversion in the amounts of water that would otherwise have been available for beneficial use below the diversion point. The estimated average seasonal amounts of the rights are set forth in the following tabulation:

<u>Capacity of diversion works, in second-feet</u>	<u>Estimated rights of downstream users to waters of Ventura River otherwise available for diversion, in acre-feet per season</u>
50	2,450
100	2,800
150	3,000
200	3,050

In all reservoir operation studies of Casitas Reservoir, an allowance was made for loss of effective storage capacity by sedimentation in the amount of 2,000 acre-feet. This value represents the estimated loss after about 20 years of operation.

It was found that the series of wet years from 1936-37 through 1943-44 would have filled Casitas Reservoir by the spring of 1944 to all storage capacities considered, and that the reservoir would have been drained in the fall of 1951. Presented in Table 53 are the estimated storage capacities required to completely regulate runoff in Coyote Creek plus inflow from the Ventura River with the four capacities of diversion conduit considered. The table also shows the estimated net safe seasonal yields that would result from construction of the indicated developments.



TABLE 53

ESTIMATED STORAGE CAPACITIES AND NET  
SAFE SEASONAL YIELDS OF CASITAS RESERVOIR FOR  
VENTURA RIVER DIVERSION CONDUIT OF VARIOUS CAPACITIES

Capacity of diversion conduit, in second-feet	: Gross reservoir storage capacity : required for complete regulation, in acre-feet	: Net safe yield, : in acre-feet : per season
0*	65,000	8,400
50	105,000	15,200
100	130,000	18,300
150	145,000	20,200
200	156,000	21,900

\* With use of Coyote Creek water alone.

Rough analysis of earlier drought periods indicated that, with the exception of the 156,000 acre-foot capacity reservoir, the drought period from 1944-45 through 1950-51 was the most severe in regard to yield for all reservoir storage capacities studied. Had a Casitas Reservoir with capacity of 156,000 acre-feet, augmented by a 200 second-foot diversion from the Ventura River, been in operation during the critical water supply period from 1922-23 through 1935-36, it was estimated that the yield shown in Table 53 would have been reduced about 1,000 acre-feet per season.

The operation studies indicated that little increase in yield would be obtained for any given size of reservoir by increasing the capacity of the diversion conduit, unless the reservoir storage capacity exceeded that required for complete regulation of inflow. However, it was found that there was a relatively small difference in estimated costs of constructing conduits of varying capacities up to 200 second-feet, as hereinafter described. For this reason, it was concluded that a conduit with 200 second-foot diversion capacity should be provided, to

assure filling of Casitas Reservoir during water supply periods with different regimens of flow than that of the base period and with possible longer and more deficient periods of drought. Table 54 presents estimates of the combined monthly inflow to Casitas Reservoir during the base period with a conduit capacity of 200 second-feet.

TABLE 54

ESTIMATED MONTHLY INFLOW TO CASITAS RESERVOIR DURING BASE PERIOD  
WITH VENTURA RIVER DIVERSION CONDUIT CAPACITY 200 SECOND-FEET

(In acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1936-37	120	80	2,420	2,000	19,740	15,040	9,200	3,700	1,610	700	300	150	55,060
1937-38	150	240	1,560	1,000	16,110	27,470	8,910	4,590	2,310	1,220	690	340	64,590
1938-39	440	500	2,550	2,980	2,190	4,060	1,280	670	150	90	70	60	15,040
1939-40	60	70	90	540	4,640	2,400	970	400	120	60	40	40	9,430
1940-41	50	60	4,610	11,940	19,630	29,040	20,380	9,790	4,290	2,710	1,530	920	104,950
1941-42	950	900	3,030	2,500	1,490	1,530	3,730	1,580	510	140	90	80	16,530
1942-43	90	90	110	17,050	11,420	19,190	5,580	3,070	1,330	560	270	160	58,920
1943-44	150	190	1,680	1,650	12,650	15,630	4,980	2,700	1,440	620	230	160	42,080
1944-45	180	1,240	750	760	7,360	4,470	2,360	1,150	440	160	100	80	19,050
1945-46	100	90	2,760	1,450	1,400	2,950	4,620	1,490	440	120	90	70	15,580
1946-47	80	1,560	3,680	2,390	1,130	880	420	120	70	40	40	30	10,440
1947-48	40	50	60	60	80	140	140	100	60	30	20	30	810
1948-49	40	50	110	120	90	350	150	150	100	50	40	30	1,280
1949-50	50	70	200	290	1,360	350	240	170	90	50	30	50	2,950
1950-51	50	70	70	100	80	100	70	60	40	20	10	10	680
Average seasonal inflow, 1936-37 through 1950-51													27,820



Estimates of the net safe seasonal yields that could be obtained with selected storage capacities of Casitas Reservoir, and with the 200 second-foot capacity diversion conduit, are shown in Table 55.

TABLE 55

ESTIMATED NET SAFE SEASONAL YIELDS  
OF CASITAS RESERVOIR FOR SELECTED STORAGE CAPACITIES,  
WITH 200 SECOND-FOOT VENTURA RIVER DIVERSION CONDUIT

(In acre-feet)

<u>Reservoir storage capacity :</u>		
<u>Gross</u>	<u>:</u>	<u>Net : Net safe yield</u>
92,000	90,000	14,000
105,000	103,000	15,600
130,000	128,000	18,600
156,000	154,000	21,900

Design Features of Ventura River-Casitas Diversion. Investigation was made of three possible sites for weirs to divert Ventura River water to Casitas Reservoir. The uppermost of the three sites considered is on the North Fork of Matilija Creek about 0.6 mile above its confluence with Matilija Creek. Diversion at this site would involve conveying a portion of the North Fork flow through a tunnel into Matilija Reservoir, with release from that reservoir conveyed through a conduit to Santa Ana Creek, a tributary of Coyote Creek above Casitas Reservoir. The middle of the three sites considered is located immediately downstream from the confluence of the North Fork and Matilija Creek, and the diversion would include a conduit leading to Santa Ana Creek over a portion of the route of the preceding alternate. The lowermost of the three diversion sites studied is about 1.3 miles downstream from the confluence of the North Fork and Matilija Creek, and about one mile upstream from Meiners Oaks. The conduit to Santa Ana Creek

from this site would also be aligned over a portion of the route utilized by the preceding alternatives. Estimates of cost for diversion works and conduits with capacities of 100 second-feet, 150 second-feet, and 200 second-feet, for each of the three sites, indicated that use of the middle site would be slightly more economical than the others. This fact, together with minor favoring engineering considerations, resulted in choice of the middle site for further study. As previously mentioned, a large diversion capacity may be needed in the future to assure filling of Casitas Reservoir under certain conditions of water supply. For this reason a diversion conduit from the Ventura River of 200 second-foot capacity was selected for cost analysis.

Preliminary designs for the diversion conduits and estimates of construction quantities were made from a profile prepared by the Ventura County Flood Control District in 1951, at a horizontal scale of one inch to 1,000 feet, and a vertical scale of one inch to 20 feet. Alignment and grade for those portions of the conduits above the limit of the County's location survey were determined by use of United States Geological Survey topographic maps at a scale of 1:24,000, and from information obtained during a field reconnaissance. Preliminary estimates of construction quantities for the diversion weirs were obtained from profiles at a scale of one inch equals 20 feet, both horizontally and vertically, prepared from field surveys by the Division of Water Resources.

The proposed diversion weir at the middle site would be of the concrete overpour type with ogee section, founded on bedrock at a stream bed elevation of 900 feet. The weir would be 10 feet in height above stream bed, and would be about 170 feet in length. Water would be diverted over a parapet wall into a side channel diversion box, and thence into a sand trap. From the sand trap, water would discharge either into a reinforced concrete pipe, 54 inches in diameter, or via sluiceways into the Ventura River. The pipe line would parallel the Ventura River on its right bank southerly for a distance of about 17,600 feet to

a point west of Meiners Oaks, where it would discharge into a canal. The canal would extend about 14,730 feet southwesterly to discharge into Santa Ana Creek, about 3.5 miles upstream from the Casitas dam site. Included in the length of canal would be two flumes, comprising a total length of about 630 feet. The canal would be shotcrete lined, and would have a 5-foot bottom width, 1.5:1 side slopes, and a depth of water of 3.2 feet, with a freeboard allowance of 1.0 foot. The slope of the canal would be 0.002, and the velocity of water flowing therein at design capacity would be 6.4 feet per second. The two flumes would be of metal construction, 8.3 feet and 8.9 feet in diameter, and with slopes of 0.0022 and 0.0014, respectively.

The location of the proposed diversion weir at the middle site, and of the approximate alignment of the conduit are shown on Plate 42, entitled "Proposed Conveyance and Distribution Systems". General features of the Ventura River-Casitas Diversion are presented in Table 56.



TABLE 56

GENERAL FEATURES OF VENTURA RIVER-CASITAS DIVERSION  
WITH CAPACITY OF 200 SECOND-FEET

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Diversión Weir

Type . . . . .	Concrete gravity weir, with ogee overpour section; side channel diversion box, with overpour parapet wall, and 5 by 5 foot slide headgates in concrete headwall, and 5 by 5 foot slide sluiceway.
Crest elevation, in feet, U.S.G.S. datum . . . . .	910
Height of weir above stream bed, in feet. . . . .	10
Length of weir, in feet. . . . .	170

## Diversión Conduit

## Pipe Line

Type . . . . .	54-inch diameter, reinforced concrete
Length, in feet. . . . .	17,600

## Canal

Type . . . . .	Trapezoidal, shotcrete lined
Length, in feet. . . . .	14,100
Side slopes. . . . .	1.5:1
Bottom width, in feet. . . . .	5.0
Depth of water, in feet. . . . .	3.2
Freeboard, in feet . . . . .	1.0
Slope. . . . .	0.002
Velocity, in feet per second . . . . .	6.4

## Flumes

Type . . . . .	Lennon metal flume - semi-circular section
Length, in feet. . . . .	600                      30
Diameter, in feet. . . . .	8.3                      8.9
Freeboard, in feet . . . . .	0.50                    0.54
Slope. . . . .	0.0022                0.0014
Velocity, in feet per second . . . . .	9.1                    7.6

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Design Features of Casitas Dam and Reservoir. As a result of the previously described geologic investigation and yield studies, preliminary estimates of cost were made for dams at the Casitas site of 178 feet, 188 feet, 202 feet, and 215 feet in height from stream bed to spillway lip, creating reservoir storage capacities of 92,000 acre-feet, 105,000 acre-feet, 130,000 acre-feet, and 156,000 acre-feet, respectively. For all heights of dam, a rolled fill structure was considered, comprising an upstream impervious section of select earth material with a downstream section of random earth material. Both upstream and downstream slopes of the dams would be 3:1, with a slope of the downstream face of the impervious section of 1:1. Crest widths for the dams would be 25 feet. Random material was chosen for downstream sections rather than pervious fill because of the absence of suitable permeable material in the area. Utilizing random fill would require installation of gravel drains to remove any small amount of leakage that might occur through the impervious section. A gravel blanket, with a thickness of 6 feet normal to the downstream slope of the impervious fill, would be placed at the contact between the impervious and random fill, and would extend to a height of two-thirds of the distance between stream bed and spillway lip. Placing the gravel blanket to this height should amply cover that portion of the face of the impervious fill within the zone of saturation. Seepage intercepted by the blanket would be discharged into four longitudinal gravel drains extending to the toe of the random fill. These drains would be about 6 feet in thickness and 15 feet in width, and would be placed along each abutment and at one-third points across the stream bed. The upstream slope of the dam would be protected against wave action by placement of riprap to a depth 3 feet normal to the slope. The downstream slope of the random section would be stabilized and protected against the erosive action of rainfall by finishing off with topsoil, rolling in barley straw, and planting of bacharis shoots. Horizontal gutters, paved with cobbles, would be provided at 30-foot vertical intervals.

It was assumed that about 50 feet of alluvial sand and gravel would have to be stripped from under the impervious section. Under the random section in the stream bed, stripping depth was estimated to be 5 feet. Stripping requirements on the left abutment were estimated to be on the order of 10 feet under the impervious section, and 5 feet under the random section. On the right abutment, stripping would average about 20 feet under the impervious section and about 10 feet under the random section.

For estimating purposes for all heights of dam considered, it was assumed that the slide existing between elevations of 325 and 425 feet in the right abutment would be removed in its entirety, thereby adding about 50,000 cubic yards to stripping requirements. It was estimated that about 80 per cent of foundation stripping would be used for random fill, thus reducing required borrow. Field investigation indicated that sufficient borrow for the impervious fill could be obtained within a distance of about 3,000 feet from the site. Stripping excavation quantities were divided into common and rock classifications, in order to take advantage of the lower unit costs for excavation of large volumes of common material with tractor-drawn scrapers. It was assumed that rock excavation in the stream bed would consist of dressing-up the foundation surface with power shovels, bulldozers, or rooters. Foundation treatment would also include moderate grouting to insure against excessive seepage. Stripping of abutments would involve excavation of soil and solid rock in moderate quantities, and/or broken rock in relatively large quantities. It was assumed that both impervious and random material would be placed with the tractor-drawn scraping equipment and compacted with sheepsfoot tampers. Gravel for the drains and pervious blanket would probably have to be imported from the Santa Clara River near Saticoy, about 20 miles in distance. The nearest known source of rock for riprap is near Matilija Dam, which is about 11 miles from the site. Access to the site during and after construction could be maintained via the Casitas Pass Road.



It is indicated that excessive leakage might occur through the relatively thin rib that forms the left abutment of the Casitas dam site, and that it might be necessary to place an impervious blanket on the upstream slope of this rib. Provision for such a blanket was not included in the estimates for the 92,000 and 105,000 acre-foot reservoirs, it being assumed that if substantial leakage were observed after construction the reservoir could be drawn down and the blanket placed at that time. For the 130,000 and 156,000 acre-foot reservoirs, dam axes were moved a short distance upstream, and blanketing of both the left and right abutments was effected by impervious fill of the dam.

Spillways for all heights of dam considered would have a discharge capacity of 17,000 second-feet, which is the estimated peak discharge of a once in 1,000-year flood. The spillways were designed as overpour chute types, with ogee weirs, concrete lined, and founded on bedrock in the left abutment. The designed maximum depth of water above the spillway lip varied from 9.4 to 11.0 feet for the several sizes of dam, and the residual freeboard comprised the remaining distance to the dam crest, which was 20 feet above the spillway lip. For the dam creating a reservoir of 92,000 acre-feet capacity, the spillway would be located in a saddle about 1,600 feet east of the center line of the stream channel. For the 105,000 and 130,000 acre-foot reservoirs, a saddle about 1,000 feet further east would be employed, whereas the spillway for the 156,000 acre-foot reservoir would be constructed about 400 feet still further to the east.

In the selection of spillway sites, consideration was given to utilization of a saddle in the reservoir rim, through which the Santa Ana Road enters the reservoir area, where spill could be discharged directly into the Ventura River. Preliminary estimates of cost indicated that this site did not compare favorably with the sites chosen.

Outlet works would be located in a circular reinforced concrete tower, located upstream from the dam on the right abutment, varying in diameter and

height in accordance with the considered height of dam. Water would enter the tower through six gate valves, which would also vary in diameter in accordance with the considered reservoir capacity. Intake to the tower would be conveyed beneath the dam in a reinforced concrete cylinder pipe. The pipe would be encased in concrete and placed in a trench excavated in the foundation along the right abutment. Placing the outlet pipe on this abutment would be contingent upon finding satisfactory foundation conditions after removal of the aforementioned slide. For the 92,000 and 105,000 acre-foot reservoirs, 42-inch diameter outlet pipes were assumed, with 48-inch diameter pipes employed in the estimates for the two larger reservoirs considered. The outlet conduit would feed into a control house where a bifurcation structure controlled by gate valves would be placed, thereby allowing water discharged from the reservoir to enter either Coyote Creek or into the proposed distribution system.

It was estimated that two years would be required for construction of the 92,000 acre-foot and 105,000 acre-foot reservoirs, three years for the 130,000 acre-foot reservoir, and four years for the 156,000 acre-foot reservoir. It was assumed that the construction schedule would be arranged so that the embankment would be placed to stream bed level prior to the first winter season. Runoff during the first season would be passed over the embankment in a channel 50 feet in width, constructed along the right abutment. Outlet works would be constructed during the second working season. For the two dams requiring in excess of two years to complete, it was assumed that the embankment would be high enough during the second winter season so that sufficient storage would be available to handle floods of record, and that releases could be effected through the outlet works.

From study of aerial photographs, it was concluded that clearing of trees and brush would be required from about one-half of the Casitas reservoir area, or from about 800 to 1,000 acres. Approximately 3.5 miles of State Highway 150, and

about 2.0 miles of county road would require relocation. Provision was made for a service road on the easterly side of the reservoir area. Relocation of certain other utilities also would be required, including a power line of the Southern California Edison Company. About 4,300 acres of privately owned lands and improvements would have to be acquired.

Estimates of costs for relocating State Highway 150, the county road, for acquisition of reservoir lands and improvements, and for relocation of utilities were made in 1951 by the Ventura County Flood Control District. A revised estimate of the cost of acquisition of lands and improvements was furnished by the Ventura County Flood Control District in 1953.

Pertinent data with respect to general features of the four sizes of dam and reservoir considered at the Casitas site, as designed for cost estimating purposes, are presented in Table 57. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with a capacity of 130,000 acre-feet are shown on Plate 26, entitled "Casitas Dam on Coyote Creek".



TABLE 57

GENERAL FEATURES OF FOUR SIZES OF DAM AND RESERVOIR  
AT THE CASITAS SITE ON COYOTE CREEK

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Earthfill Dam

Crest elevation, in feet, U.S.G.S. datum . . . . .	523	533	547	560
Crest length, in feet. . . . .	1,665	1,695	2,540	3,970
Crest width, in feet. . . . .	25	25	25	25
Height, spillway lip above stream bed, in feet . . . . .	178	188	202	215
Side slopes, upstream and downstream. . .	3:1	3:1	3:1	3:1
Freeboard above spillway lip, in feet. . . . .	10.6	9	9	8.5
Elevation of stream bed, in feet, U.S.G.S. datum. . .	325	325	325	325
Volume of fill, in cubic yards . . . .	4,715,400	5,461,800	6,934,100	12,441,800

Reservoir

Surface area at spillway lip, in acres . . . . .	1,375	1,530	1,790	2,000
Gross storage capacity at spillway lip, in acre-feet. . . . .	92,000	105,000	130,000	156,000
Type of spillway . .	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute
Spillway discharge capacity, in second-feet . . . .	17,000	17,000	17,000	17,000
Type of outlet . . .	Concrete tower with 42-inch diameter reinforced concrete cylinder pipe beneath dam, encased in concrete	Concrete tower with 42-inch diameter reinforced concrete cylinder pipe beneath dam, encased in concrete	Concrete tower with 48-inch diameter reinforced concrete cylinder pipe beneath dam, encased in concrete	Concrete tower with 48-inch diameter reinforced concrete cylinder pipe beneath dam, encased in concrete

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Summary of Estimated Costs. Presented in Table 58 is a summary comparison of capital and annual costs of the four considered sizes of dam and reservoir at the Casitas site, and of the Ventura River-Casitas diversion with a capacity of 200 second-feet. Also presented in Table 58 are estimated unit costs of storage capacity and net safe yield of water that would result with construction of the indicated works. Certain of these latter relationships are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the four sizes of dam and reservoir, and for the Ventura River-Casitas diversion works and conduit, are presented in Appendix C.

TABLE 58

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND  
YIELDS OF WATER AT THE CASITAS SITE ON COYOTE CREEK,  
WITH DIVERSION FROM  
VENTURA RIVER OF 200 SECOND-FOOT CAPACITY

Item	Reservoir storage capacity, in acre-feet			
	92,000	105,000	130,000	156,000
Capital Costs				
Dam and reservoir	\$ 8,938,000	\$ 9,678,000	\$ 11,763,000	\$19,636,000
Ventura River-				
Casitas diversion	<u>1,112,000</u>	<u>1,112,000</u>	<u>1,112,000</u>	<u>1,112,000</u>
Totals	10,050,000	10,790,000	12,875,000	20,748,000
Cost per acre-foot of storage capacity	109	103	99	133
Cost per acre-foot of net safe yield	718	692	692	947
Annual Costs				
Dam and reservoir	\$467,000	\$507,000	\$615,000	\$1,017,000
Ventura River-				
Casitas diversion	<u>60,000</u>	<u>60,000</u>	<u>60,000</u>	<u>60,000</u>
Totals	527,000	567,000	675,000	1,077,000
Costs per acre-foot of net safe yield	38	36	36	49
Cost per acre-foot of incremental net safe yield	---	25	36	121

Ferndale Dam and Reservoir. The Ferndale dam site is located on

Santa Paula Creek about 0.4 mile southeast of its confluence with Sisar Creek, a principal tributary, and in Section 16, Township 4 North, Range 21 West, S.B.B. & M. State Highway 150, paralleling Santa Paula Creek, passes along the right abutment of the dam site, and traverses a portion of the reservoir area. Stream bed elevation at the dam site is about 910 feet, U.S.G.S. datum. Consideration was given to the construction of a dam and reservoir at the Ferndale site for storage of flood waters in Santa Paula Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The drainage area of Santa Paula Creek above the Ferndale dam site comprises about 36 square miles, and produced an estimated average seasonal runoff during the base period of about 15,700 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 12,000 acre-feet per season during the base period with the present pattern of land use and water supply development.

The Ferndale dam site was mapped up to an elevation of 1,225 feet in August, 1951, by the Ventura County Flood Control District, at a scale of one inch equals 200 feet, with a 5-foot contour interval. Reservoir areas and capacities for various heights of dam were obtained from available advance sheets of U.S.G.S. quadrangles, at a scale of 1:24,000 with a 20-foot contour interval. Storage capacities of Ferndale Reservoir at various stages of water surface elevation are given in Table 59.



TABLE 59

## AREAS AND CAPACITIES OF FERNDALE RESERVOIR

Depth of water : at dam, in feet:	: Water surface elevation, U.S.G.S. datum, : in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	910	0	0
10	920	5	15
20	930	7	75
30	940	9	155
40	950	12	260
50	960	15	390
60	970	26	600
70	980	37	910
80	990	47	1,330
90	1,000	58	1,850
100	1,010	78	2,530
110	1,020	99	3,400
120	1,030	120	4,500
130	1,040	140	5,800
140	1,050	160	7,310
150	1,060	185	9,050
160	1,070	210	11,000
165	1,075	220	12,100
170	1,080	230	13,200
180	1,090	250	15,600
190	1,100	270	18,200
200	1,110	290	21,000
210	1,120	310	24,000
220	1,130	330	27,200
230	1,140	350	30,600
240	1,150	380	34,200
250	1,160	400	38,100
260	1,170	430	42,300
270	1,180	450	46,700
280	1,190	480	51,300
290	1,200	510	56,300

A geologic investigation of the Ferndale dam site was made in 1951 by geologists of the Division of Water Resources. No prior geologic work at this site is known, nor has the site been drilled. Available information indicates that the site is suitable for construction of an earthfill or rockfill dam up to a maximum height of about 270 feet.

Formations at the dam site consist mainly of shale of the Modelo formations and extensive unconsolidated terrace deposits. Upstream from the site, Rincon shale, Pico sediments, Matilija sandstones, and Cozy Dell shale were noted, while Santa Margarita sandstone is in evidence immediately downstream from the site. Terrace deposits occur at various levels, varying from poorly stratified to unstratified in character, and apparently include old stream deposits, land slide, and colluvial material. Most of the terrace deposits contain many pebbles and cobbles, and in the case of the higher terraces include subangular blocks. The amount of fines in the terraces varies considerably, from limited quantities to instances where the amount of such binder material is appreciable. The shale exhibits considerable contortion and folding, with the strike varying from about North 60 degrees East to North 80 degrees East, and with a dip varying from about 55 degrees east to steep overturned dips to the southeast. A zone of thick colluvial cover, land slide material, and extensive travertine deposits occurs on the right abutment upstream from the dam axis.

Two major faults were identified in the vicinity of the site, together with a number of minor faults and shears. A fault trending about North 80 degrees East crosses Santa Paula Creek about 1,000 feet downstream from the dam site. The San Cayetano fault has been mapped, trending in a east-west direction about 1,500 north of the site. However, the Ferndale dam site appears to be free from major faults, so far as could be determined.

Based on estimates of runoff during the base period, yield studies

were made for reservoir storage capacities at the Ferndale site of 12,000 acre-feet, 24,000 acre-feet, and 34,000 acre-feet, respectively. Runoff at the site was estimated to be 92 per cent of measured runoff at the U.S.G.S. stream gaging station on Santa Paula Creek near Santa Paula. Estimated monthly runoff of Santa Paula Creek at the Ferndale dam site during the base period is presented in Table 60.



TABLE 60

ESTIMATED MONTHLY RUNOFF OF SANTA PAULA CREEK AT FERNDALE DAM SITE DURING BASE PERIOD  
(In acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1936-37	460	220	1,370	1,910	9,600	8,630	3,860	1,560	740	480	280	250	29,360
1937-38	260	240	950	500	9,380	22,460	3,020	1,660	930	720	370	310	40,800
1938-39	310	300	1,640	1,150	760	1,440	750	380	240	200	150	470	7,790
1939-40	190	100	210	550	1,740	730	550	300	190	80	70	80	4,790
1940-41	100	110	910	2,750	11,140	19,190	11,710	3,360	1,590	1,060	650	510	53,080
1941-42	480	380	1,300	920	550	510	1,110	510	250	180	80	90	6,360
1942-43	110	130	170	11,950	6,880	11,780	2,370	1,220	710	530	380	320	36,550
1943-44	300	300	930	800	4,970	8,250	2,330	1,170	620	400	290	280	20,640
1944-45	290	990	410	400	3,250	2,460	1,490	760	520	280	200	160	11,210
1945-46	200	210	2,360	640	610	2,190	2,350	800	440	220	150	120	10,290
1946-47	150	1,690	1,980	990	520	450	350	260	130	80	50	90	6,740
1947-48	80	110	160	120	140	210	340	170	70	80	50	40	1,570
1948-49	60	50	130	200	190	560	240	170	100	60	40	20	1,820
1949-50	40	140	240	420	1,180	360	340	190	130	70	50	50	3,210
1950-51	50	90	120	130	120	160	100	80	20	20	0	10	900
Average seasonal runoff, 1936-37 through 1950-51													15,670

In all of the studies an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 2,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 1.70 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies.

<u>Month</u>	<u>Net evaporation in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.15	April	0.15
November	0.06	May	0.19
December	0.04	June	0.21
January	0.04	July	0.25
February	0.05	August	0.25
March	0.10	September	0.21
			<hr/>
	Total		1.70

Monthly studies of operation of Ferndale Reservoir during the base period were made for the three sizes of reservoir considered under both the uniform release and rapid release methods of operation.

The estimated values of net safe seasonal yields that would be obtained under both the uniform release and rapid release operating criteria are presented in Table 61. The relationship between reservoir storage capacity and net safe seasonal yield, with Ferndale Reservoir operated by the uniform release method and with releases for maintenance of water levels in Santa Paula Basin, is depicted graphically on Plate 36.

TABLE 61

## ESTIMATED NET SAFE SEASONAL YIELDS OF FERNDALE RESERVOIR

(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	: Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : with releases for : maintenance of : ground water levels :	: Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : without releases : for maintenance of : ground water levels :	: Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits : Available within : Santa Clara River : Hydrologic Unit : :	: Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits : :
12,000	2,500	4,000	2,500	2,000
24,000	4,900	6,500	4,900	3,000
34,000	6,600	8,500	6,700	4,200

As a result of the geologic investigation and the reservoir yield studies, estimates of cost were prepared for dams at the Ferndale site with heights of 165 feet, 210 feet, and 240 feet from stream bed to spillway lip, creating reservoir storage capacities of 12,000 acre-feet, 24,000 acre-feet, and 34,000 acre-feet, respectively. For all heights of dam, a rolled fill structure was contemplated, comprising an impervious core of select earth material, and upstream and downstream sections of pervious free draining material. Both upstream and downstream slopes of the dam would be 2.5:1 for the dams of 165-foot and 210-foot height, and 3:1 for the dam of 240-foot height. The impervious sections would have upstream and downstream slopes of 1:1. Crest widths would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream pervious sections. The upstream face of the dam would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope.

In the cost estimates, it was assumed that a depth of about 8 feet of sand and gravel would be stripped in the channel under the impervious core. On the left abutment, depths of from 5 to 50 feet of terrace material and from 4 to 6 feet of fractured shale would be removed. Under the impervious section on the right abutment, stripping requirements were estimated to comprise a depth of about 2 feet of surface soil, plus an average depth of about 12 feet



of fractured shale. The cost estimates do not include provisions for removal of the aforementioned land slide and colluvial material from this abutment. Further exploratory work and examination during construction would be required to indicate the amount of additional stripping needed in this area. For the pervious sections, a nominal depth of stripping of 2 feet was assumed throughout the contact area. During actual construction, increased stripping might be required under the pervious sections of the dam to stabilize slopes, particularly in the land slide area on the right abutment. It was assumed that foundation treatment would include moderate grouting.

It is indicated that adequate material for the impervious section of Ferndale Dam is available within one mile upstream and downstream from the site. In this connection, it was assumed that terrace material stripped from the left abutment would be almost entirely usable in the impervious section. Two samples of material, taken from other possible borrow areas, were tested by the Division of Water Resources and were deemed adequate for use in the impervious section. Sufficient borrow material suitable for the pervious sections of Ferndale Dam is likewise available within about a mile of the site. It was estimated that a portion of the material stripped beneath the impervious section, and too coarse for use therein, would be used in the pervious sections. Matilija sandstone, outcropping about one mile upstream from the site, could be quarried for riprap. It was assumed that compaction of the impervious section of the dam would be effected by either sheeps-foot tampers or pneumatic rollers, and that pneumatic rollers would be used to compact the pervious section.

Spillways, for all heights of dams considered, would have a discharge capacity of 37,000 second-feet, which is the estimated peak discharge of a once in 1,000-year flood. The spillways were designed as concrete-lined overpour chutes, with ogee-weir control sections. For the two smaller dams, the spillway weir and chute channel would be excavated across the terrace easterly

on the left abutment, and would discharge into a small ravine a short distance downstream from the dam. For the largest of the dams considered, topographic considerations required that the spillway be located across the right abutment. Depth of water above the spillway lip at design discharge capacity would be 20 feet for the dam of 165 foot height, and 25 feet for the dams of both 210 and 240 foot height. A depth of 5 feet of residual freeboard was provided in the spillways for each of the three heights of dam.

As it was estimated that the dam of 165 foot height could be constructed in one year, it was assumed that diversion of summer flow in Santa Paula Creek would be effected through the outlet conduit. For the dams with heights of 210 and 240 feet, requiring an estimated two years for construction, it was assumed that a 15-foot diameter concrete lined tunnel of horseshoe section would be constructed through the right abutment to provide for diversion of winter flows. The tunnel would be about 1,250 feet in length for the smaller dam and about 1,600 feet in length for the larger.

It was assumed that outlet works for both of the larger dams would utilize the diversion tunnel after construction. The approach channel for the outlet works would be 100 feet in length, with a varying bottom width and 1:1 side slopes. Maximum depth of cut would be about 40 feet. A submerged concrete intake structure would be located immediately upstream from the tunnel portal. This structure would consist of a concrete chamber, wherein would be located hydraulic and manual controls for a high pressure steel slide gate which would regulate discharge through the outlet pipe. The intake for the outlet pipe would be located about 20 feet above the floor of the tunnel. The outlet conduit would be placed in the tunnel, and would consist of 60-inch diameter steel pipe, supported by ring girders resting on the floor of the tunnel. The conduit would terminate at a control house located at the downstream portal of the tunnel, wherein releases would be further regulated by a 48-inch diameter needle valve. Access to the outlet pipe and intake structure would be main-

tained through the diversion tunnel.

For the dam with height of 165 feet, the outlet works would consist of an intake structure similar to those described for the two higher dams, from which water would discharge into a 42-inch diameter steel pipe. The pipe would be supported on ring girders and would be placed within a reinforced concrete conduit, 8 feet in diameter and horseshoe in section. The conduit would be placed in a trench excavated to sound rock across the right abutment, and would terminate at a control house at the downstream toe of the dam. Releases to the outlet pipe would be regulated at the intake structure by a high pressure steel slide gate, operated by controls similar to those for the two higher dams. Further regulation of reservoir releases would be obtained by installing a 36-inch diameter needle valve at the downstream end of the outlet pipe. Access to the pipe and intake structure would be maintained through the outlet conduit.

Construction of a dam at the Ferndale site would require the relocation of about 3.5 miles of State Highway 150. The cost of this relocation was estimated by the Ventura County Flood Control District in 1953 to be about \$420,000. Included in the reservoir area is one large ranch, minor agricultural developments, and several small resort and suburban developments. In 1953 the Ventura County Flood Control District also estimated the cost of lands and improvements up to an elevation of 1,100 feet, which would accommodate a reservoir with storage capacity 12,000 acre-feet, and to an elevation of 1,200 feet, which would be required for storage capacities up to 34,000 acre-feet. These estimates do not include the cost of acquiring mineral rights in the reservoir area, which rights could substantially increase estimated acquisition costs. From the results of field examination by the Division of Water Resources, it was estimated that depending on the height of dam, from 270 to 450 acres of trees and brush in the reservoir area would require removal.



Presented in Table 62, are pertinent data with respect to the general features of the three sizes of dam and reservoir considered at the Ferndale site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 12,000 acre-feet, are shown on Plate 27, entitled "Ferndale Dam on Santa Paula Creek."

TABLE 62

GENERAL FEATURES OF THREE SIZES OF DAM AND RESERVOIR  
AT THE FERNDAL SITE ON SANTA PAULA CREEK

Earthfill Dam				
Crest elevation, in feet, U.S.G.S. datum	1,100	1,150	1,180	
Crest length, in feet	990	1,240	1,390	
Crest width, in feet	30	30	30	
Height, spillway lip above stream bed, in feet	165	210	240	
Side slopes, upstream and downstream	2.5:1	2.5:1	3:1	
Freeboard, above spillway lip, in feet	25	30	30	
Elevation of stream bed, in feet, U.S.G.S. datum	910	910	910	
Volume of fill, in cubic yards	2,311,400	4,101,300	6,334,800	
Reservoir				
Surface area at spillway lip, in acres	220	310	380	
Gross storage capacity at spillway lip, in acre-feet	12,000	24,000	34,000	
Type of spillway	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	
Spillway discharge capacity, in second-feet	37,000	37,000	37,000	
Type of outlet	42-inch diameter steel pipe, beneath dam in reinforced concrete conduit	60-inch diameter steel pipe, through diversion tunnel	60-inch diameter steel pipe, through diversion tunnel	

Presented in Table 63 is a summary comparison of capital and annual costs of the three considered sizes of dam and reservoir at the Ferndale site. Also presented in Table 63 are estimated unit costs of storage capacity and net safe yields of water that would be developed by construction of the three sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation. Certain of the relationships presented in Table 63 are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the three sizes of dam and reservoir at the Ferndale site are included in Appendix C.

TABLE 63

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF WATER AT THE FERNDALE SITE ON SANTA PAULA CREEK

Item	Reservoir storage capacity, in acre-feet		
	12,000	24,000	34,000
Capital Costs			
Dam and reservoir	\$5,374,000	\$7,249,000	\$9,865,000
Cost per acre-foot of storage	448	302	290
Cost per acre-foot of net safe yield	2,150	1,480	1,500
Annual Costs			
Dam and reservoir	277,000	373,000	505,000
Cost per acre-foot of net safe yield	110	76	77
Cost per acre-foot of incremental net safe yield	---	40	78

Cold Spring Dam and Reservoir. The Cold Spring dam site is located on the upper reaches of Sespe Creek, in Section 6, Township 5 North, Range 22 West, S.B.B. & M. The site is about three miles downstream from the U. S. Highway 399 bridge across Tule Creek, a tributary of Sespe Creek. Stream bed elevation at the site is about 3,200 feet above an assumed datum of the Santa Clara Water Conservation District which approximates an elevation of 3,190 feet, U.S.G.S. datum. The dam site and most of the reservoir area are located on federally owned land within the Los Padres National Forest. Consideration was given to the construction of a dam and reservoir at the Cold Spring site for storage of flood waters in Sespe Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The drainage area of Sespe Creek above the Cold Spring dam site comprises about 65 square miles, and produced an estimated average seasonal runoff during the base period of about 16,800 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 14,500 acre-feet per season during the base period with the present pattern of land use and water supply development.

The Cold Spring dam site was mapped up to an elevation of 3,550 feet in 1932, by V. M. Freeman for the Santa Clara Water Conservation District, at a scale of one inch equals 100 feet, with contour interval of 10 feet. In 1925, J. B. Lippincott mapped the reservoir area up to an elevation of 3,410 feet, at a scale of one inch equals 600 feet, with contour interval of 10 feet. Reservoir areas and storage capacities at various stages of water surface elevation, computed from this map, are given in Table 64, but the elevations have been adjusted to the datum of the Santa Clara Water Conservation District dam site map by subtracting 10 feet. Above an elevation of 3,410 feet, the capacities were computed using areas measured from Army Map Service quadrangles, at a scale of 1:31,680, and with a contour interval of 50 feet. As previously stated, U.S.G.S. datum is approximately 10 feet lower than District datum.



TABLE 64

## AREAS AND CAPACITIES OF COLD SPRING RESERVOIR

Depth of water at dam, in feet	:	Water surface elevation District datum, in feet	:	Water surface area, in acres	:	Storage capacity, in acre-feet
0		3,200		0		0
10		3,210		2		10
20		3,220		10		70
30		3,230		22		230
40		3,240		35		515
50		3,250		55		965
60		3,260		70		1,590
70		3,270		95		2,410
80		3,280		125		3,520
90		3,290		160		4,930
100		3,300		200		6,700
110		3,310		230		8,810
120		3,320		260		11,200
130		3,330		290		14,000
140		3,340		350		17,200
150		3,350		410		21,000
160		3,360		480		25,400
170		3,370		550		30,600
178		3,378		610		35,000
180		3,380		620		36,400
190		3,390		690		43,000
200		3,400		760		50,200
210		3,410		840		58,300
220		3,420		920		67,100
230		3,430		990		76,700
240		3,440		1,070		87,000
250		3,450		1,140		98,000
252		3,452		1,160		100,000
260		3,460		1,220		109,800
270		3,470		1,290		122,300
280		3,480		1,350		135,500
290		3,490		1,420		149,400
300		3,500		1,490		164,000
310		3,510		1,560		179,200

Based upon preliminary geological reconnaissance, the Cold Spring dam site is considered suitable for a properly constructed earthfill, rockfill, or masonry type of dam of low to moderate height. Geology was investigated by the Division of Water Resources in March, 1952. Two test pits and five core holes, totaling 586 feet in length, were drilled in 1948 by the Ventura County Flood Control District, and the cores were classified by Dr. T. L. Bailey, Consulting Geologist. Previous geologic studies of the site were made by Dr. Charles P. Berkey, Paul F. Kerr, and Hyde Forbes in the early thirties.

The rocks at the Cold Spring site are a gently dipping series of thick-bedded to massive fine-grain sandstones and more thinly bedded siltstones. A small amount of true shale is also present. The sandstones generally contain a considerable amount of silt, and perhaps some clay. The rocks probably belong to the Cozy Dell formation of Eocene age.

The beds on both abutments average nearly east-west in strike, and apparently without exception dip to the north on the flank of an anticline whose axis lies about three-quarters of a mile south of the site. The strike varies locally, largely because of a notable tendency of the beds to thicken or pinch out in short distances. No close folding or contortion of the bed was observed. The northerly dip varies from about 3 to about 20 degrees.

The rocks at the dam site are only moderately jointed, and no shearing or faulting was noted. The possible presence of a fault on the right abutment has been reported. More detailed exploration here is desirable if a dam is to be further considered at this site, but it is not believed that any fault on this abutment would be a major problem.

There is considerable uncertainty concerning the amount of runoff produced by the Sespe Creek watershed above the Cold Spring site. A U.S.G.S. stream gaging station on Sespe Creek near Wheeler Springs was established in 1948. This station is located about five miles upstream from the Cold Spring dam site, and measures runoff from about 50 square miles of watershed, or about

20 per cent of that at the U.S.G.S. stream gaging station on Sespe Creek near Fillmore, above which the drainage area comprises about 254 square miles. From 1948-49 through 1951-52, there occurred three relatively dry seasons and one wet season. Recorded runoff at the station near Wheeler Springs during the three dry seasons from 1948-49 through 1950-51 was about 5.5 per cent of that at the station near Fillmore. However, during the wet season of 1951-52 the runoff at the upper station was about 12 per cent of that at the lower station. It is indicated, therefore, that with an increase in relative wetness of a given season, the percentage of runoff at the upper station increases as compared with runoff at the lower station, and that runoff from various portions of the watershed is not proportional to the ratio of respective drainage areas.

During the base period, the maximum recorded seasonal flow of Sespe Creek near Fillmore was about 376,000 acre-feet in 1940-41, including corrections for upstream impairments. It was estimated that during such a wet season the runoff produced by the watershed above the station near Wheeler Springs would be equal to about 20 per cent of that above the station near Fillmore. Thus, it was assumed that for seasons producing runoff in excess of about 376,000 acre-feet at the Fillmore station, runoff at the upper station would be proportional to the ratio of the respective drainage areas. For seasons with lesser amounts of runoff at the lower station, runoff at the upper station was estimated from a curve drawn to show the relationship of runoff of Sespe Creek near Fillmore with that of Sespe Creek near Wheeler Springs during the four seasons of overlapping record. From this curve, runoff for each of the seasons of the base period without record at the Wheeler Springs stream gaging station was estimated.

To derive seasonal runoff at the Cold Spring dam site, estimated or measured seasonal runoff at the Wheeler Springs stream gaging station was increased by 30 per cent, or in proportion to the ratio of the respective drainage areas. Monthly distribution of seasonal runoff at the Cold Spring dam site



for each season of the base period was estimated from the measured monthly percentage of seasonal runoff for Sespe Creek near Fillmore during seasons from 1936-37 through 1947-48, and from similar data for Sespe Creek near Wheeler Springs during seasons subsequent to 1947-48. Presented in Table 65 is the estimated monthly runoff of Sespe Creek at the Cold Spring dam site during the base period.

TABLE 65

## ESTIMATED MONTHLY RUNOFF OF SESPE CREEK AT COLD SPRING DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1936-37	500	110	2,480	1,890	10,720	8,770	2,610	950	450	200	130	100	28,910
1937-38	120	160	780	430	13,790	26,470	2,780	1,470	790	470	280	250	47,790
1938-39	100	110	750	660	400	880	310	170	100	50	40	250	3,820
1939-40	70	60	70	220	1,030	360	220	100	50	20	20	20	2,240
1940-41	110	100	4,660	8,840	26,390	32,840	17,730	4,440	1,880	1,020	650	490	99,150
1941-42	150	160	780	440	280	290	760	250	110	50	40	30	3,340
1942-43	70	100	130	9,840	6,520	9,070	1,400	690	370	210	140	100	28,640
1943-44	100	130	1,220	720	5,650	9,160	2,250	970	550	280	170	120	21,320
1944-45	80	600	190	150	1,920	970	510	210	120	60	50	30	4,890
1945-46	50	80	1,700	280	290	1,870	1,390	300	110	60	40	30	6,200
1946-47	30	930	1,530	460	230	190	140	80	50	30	20	20	3,710
1947-48	20	20	30	30	50	110	120	60	30	10	10	10	500
1948-49	10	20	50	60	60	180	120	100	40	10	10	10	670
1949-50	0	20	120	120	260	140	140	80	30	10	0	0	920
1950-51	0	10	20	50	50	80	50	40	10	0	0	0	310
Average seasonal runoff, 1936-37 through 1950-51													16,830

Based on the estimates of runoff, monthly studies of operation of Cold Spring Reservoir during the base period were made for four sizes of reservoir of 15,000 acre-foot, 43,000 acre-foot, 77,000 acre-foot, and 100,000 acre-foot storage capacity, under both the uniform release and rapid release methods of operation.

In all of the studies, an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 3,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 1.70 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies.

Month	<u>Net evaporation, in feet of depth</u>	Month	<u>Net evaporation in feet of depth</u>
October	0.15	April	0.15
November	0.06	May	0.19
December	0.04	June	0.21
January	0.04	July	0.25
February	0.05	August	0.25
March	0.10	September	<u>0.21</u>
		TOTAL	1.70

The estimated values of net safe seasonal yield that would be obtained under both the uniform release and rapid release operating criteria, are presented in Table 66. The relationship between reservoir storage capacity and net safe seasonal yield, with Cold Spring Reservoir operated by the uniform release method with releases for maintenance of water levels in Fillmore and Santa Paula Basins is depicted graphically on Plate 36.



TABLE 66  
ESTIMATED NET SAFE SEASONAL YIELDS OF COLD SPRING RESERVOIR  
(In acre-feet)

	Uniform release operation		Rapid release operation	
	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : with releases for : maintenance of : ground water levels :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : without releases : for maintenance of : ground water levels :	Available to Oxnard : Forebay, Oxnard : Available within : Santa Clara River : Hydrologic Unit : :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits : :
Reservoir storage capacity				
35,000	5,000	5,500	5,100	3,500
43,000	6,500	7,000	6,600	4,200
77,000	10,500	11,800	11,600	6,600
100,000	12,000	13,800	12,200	8,800

As a result of the geologic investigation and the reservoir yield studies, estimates of cost were prepared for dams at the Cold Spring site with heights of 178 feet, 190 feet, 230 feet, and 252 feet from stream bed to spillway lip, creating reservoir storage capacities of 35,000 acre-feet, 43,000 acre-feet, 77,000 acre-feet, and 100,000 acre-feet, respectively. For all heights of dam, a rolled fill structure was contemplated, comprised of an impervious core of select earth material, and upstream and downstream sections of random material. Both upstream and downstream slopes of the dam would be 3:1 for the dams of 178-foot, 190-foot, and 230-foot height, and 3.25:1 for the dam of 252 foot height. The impervious sections would have upstream and downstream slopes of 1:1. Crest widths would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream random sections.

The foregoing selection of random rather than pervious fill for the outer sections of the dam resulted from the absence of suitable permeable material in the area. Employment of the random fill would necessitate the installation of gravel drains in the downstream portion of the dam, to remove any leakage that might occur through the impervious section. A gravel blanket, with a thickness of 6 feet normal to the downstream slope of the impervious fill, would be placed at the contact between the impervious and random fill,

and would extend to a height of two-thirds of the distance between stream bed and spillway lip. Placing the gravel blanket to this height should amply cover that portion of the face of the impervious fill within the zone of saturation. Seepage intercepted by the blankets would be distributed into four longitudinal gravel drains extending to the toe of the random fill. These drains would be about 6 feet in thickness and 15 feet in width, and would be placed along each abutment and at the one-third points across the stream bed. The upstream face of the dam would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope. The downstream face of the dam would be stabilized and protected against the erosive action of rainfall by finishing off with top soil, rolling in barley straw, and planting bacharis shoots. Horizontal gutters, paved with cobbles, would be provided at 30-foot vertical intervals.

In the cost estimates, it was assumed that a depth of about 18 feet of sand and gravel would be stripped in the channel under the impervious core. On the left abutment, depths of 7 feet of rocky talus material, plus an additional 5 feet of bedrock, would be stripped for a vertical distance of about 100 feet above stream bed. Above this elevation the abutment consists of massive sandstone and thinner bedded siltstone outcrops, of which a depth of 5 feet would be stripped under the impervious core. Under the impervious section of the right abutment, depths of about 2 feet of soil and weathered rock, plus 5 feet of underlying jointed bedrock, would be stripped. For the random fill sections, a nominal depth of stripping of 2 feet was assumed throughout the contact area. It was assumed that foundation treatment would include moderate grouting.

Earthfill material considered suitable for the impervious section of the dam occurs in limited quantities in terraces both upstream and downstream from the site, but would probably require some sorting. By utilizing Rose Valley, about two miles from the dam site, as a borrow source for fill, it was estimated that sufficient material would be available for dams up to 272 feet in height.

Two samples of material, taken from possible borrow areas, were tested by the Division of Water Resources and were deemed adequate for use in the impervious section. Borrow material suitable for the random sections is available in somewhat limited quantities from stream gravels and from the coarse fraction in the aforementioned terrace deposits. It was estimated that a portion of the material stripped beneath the impervious section would be used in the random sections. The sandstones of the area would be quarried for riprap. It was assumed that compaction of fill material in both the impervious and random sections of the dam would be effected by either sheepsfoot tampers or pneumatic rollers. Gravel for the drains and pervious blanket would probably have to be imported from Cuyama Valley, where Tinta and Castle Creeks enter into the Cuyama River, about 24 miles distant.

Spillways, for all heights of dams considered, would have a discharge capacity of 50,000 second-feet, which is the estimated peak discharge of a once in 1000-year flood. The spillways were designed as concrete lined overpour chutes with ogee-weir control sections. For the dam of 178 foot height, the maximum depth of water above the spillway lip would be 17 feet, 5-foot residual freeboard. For the three larger dams, the maximum depth of water above the spillway lip would be 15 feet, with an additional 5 feet of residual freeboard. The spillway weirs and channels would be excavated across the nose of the left abutment, and would discharge into a small ravine downstream from the toe of the dam.

As it was estimated that the dams of 178 and 190 foot height, could be constructed in one year, it was assumed that diversion of waters in Sespe Creek would be effected through the outlet conduit. For the dams of 230 and 252 foot height, requiring an estimated two years for construction, it was assumed that a 16-foot diameter concrete lined tunnel of horseshoe section would be constructed through the left abutment to provide for diversion of winter flows. The tunnel would be about 1,520 feet in length for both dams.



It was assumed that outlet works for both of the larger dams would utilize the diversion tunnel after construction. The approach channel for the outlet works would be 90 feet in length, with a varying bottom width and 1:1 side slopes. Maximum depth of cut would be about 40 feet. A submerged concrete intake structure would be located immediately upstream from the tunnel portal. This structure would consist of a concrete chamber, wherein would be located hydraulic and manual controls for a high pressure slide gate which would regulate discharge through the outlet pipe. The intake for the outlet pipe would be located about 25 feet above the floor of the tunnel. The outlet conduit would be placed in the tunnel, and would consist of 60-inch diameter steel pipe, supported by ring girders resting on the floor of the tunnel. The conduit would terminate at a control house located at the downstream portal of the tunnel, wherein releases would be regulated by a 54-inch diameter Howell-Bunger valve. Access to the pipe and intake structure would be maintained through the diversion tunnel.

For the dams with heights of 178 and 190 feet, the outlet works would consist of an intake structure similar to those described for the two higher dams, from which water would discharge into a 54-inch diameter steel pipe. The pipe would be supported on ring girders and would be placed within a reinforced concrete conduit, 9.5 feet in diameter and horseshoe in section. The conduit would be placed in a trench excavated to sound rock across the left abutment, and would terminate at a control house at the downstream toe of the dam. Releases to the outlet pipe would be regulated at the intake structure by a high pressure steel slide gate, operated by controls similar to those for the two higher dams. Further regulation of reservoir release would be obtained by installing a 48-inch diameter Howell-Bunger valve at the downstream end of the outlet pipe. Access to the pipe and intake structure would be maintained through the outlet conduit.

The Cold Spring dam and reservoir area is owned by the United States

Government, except for one privately owned ranch containing about 44 acres. This ranch lies primarily along the bed of Sespe Creek, and is moderately rolling and undulating land, containing a small orchard, six modest frame buildings, and an outbuilding of the cabin type. The Ventura County Flood Control District, in January, 1952, estimated the cost of acquisition of the privately owned land and improvements to be \$25,000. This amount does not include the cost of acquiring mineral rights in the reservoir area. The property has been leased for oil speculation, but the nearest drilling activity is a wildcat well several miles distant. Construction of the three larger dams at the Cold Spring site would require the relocation of about 27,000 lineal feet of U. S. Highway 399, and of two bridges, one crossing Tule Creek and the other Sespe Creek. No road relocation would be required for construction of the smallest of the four dams. An estimate of cost of relocating U.S. Highway 399 was made by the California Division of Highways in 1953. It was assumed that construction of an all purpose access road, approximately two miles in length, would be required for construction of all heights of dam. From the results of field examination of the reservoir area, it was estimated that, depending on the height of dam to be constructed, from 760 to 1,290 acres of minor clearing in the reservoir area would be required.

Presented in Table 67 are pertinent data with respect to the general features of the four sizes of dams and reservoirs considered at the Cold Spring site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 35,000 acre-feet are shown on Plate 28 entitled "Cold Spring Dam on Sespe Creek".

TABLE 67

GENERAL FEATURES OF FOUR SIZES OF DAM AND  
RESERVOIR AT THE COLD SPRING SITE ON SLSPE CREEK

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Earthfill Dam

Crest elevation, in feet, Santa Clara Water Conservation District datum . . .	3,400	3,410	3,450	3,472
Crest length, in feet . . . . .	730	770	860	920
Crest width, in feet . . . . .	30	30	30	30
Height, spillway lip above stream bed, in feet. . . . .	178	190	230	252
Side slopes, upstream and downstream . . .	3:1	3:1	3:1	3.25:1
Freeboard, above spillway lip, in feet . . . . .	22	20	20	20
Elevation of stream bed, in feet, Santa Clara Water Conservation District datum. . . . .	3,200	3,200	3,200	3,200
Volume of fill, in cubic yards. . . . .	1,919,600	2,246,500	3,403,000	4,569,100

Reservoir

Surface area at spillway lip, in acres. . . . .	606	690	995	1,156
Gross storage capacity at spillway lip, in acre-feet . . . .	35,000	43,000	77,000	100,000
Type of spillway. . .	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute
Spillway discharge capacity, in second-feet . . . . .	50,000	50,000	50,000	50,000
Type of outlet. . . .	54-inch diameter steel pipe beneath dam	54-inch diameter steel pipe beneath dam	60-inch diameter steel pipe through diversion tunnel	60-inch diameter steel pipe through diversion tunnel

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Presented in Table 68 is a summary comparison of capital and annual costs of the four considered sizes of dams and reservoirs at the Cold Spring site. Also presented in Table 68 are estimated unit costs of storage capacity and net safe yield of water that would be developed by construction of the four sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. Certain of the relationships presented in Table 68 are depicted graphically on Plates 35, 36 and 37. Detailed estimates of cost for the four sizes of dam and reservoir at the Cold Spring site are included in Appendix C.

TABLE 68

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF WATER  
AT THE COLD SPRING SITE ON SESPE CREEK

Item	Reservoir storage capacity in acre-feet			
	35,000	43,000	77,000	100,000
Capital Costs				
Dam and reservoir	\$3,796,000	\$5,613,000	\$7,283,000	\$8,571,000
Cost per acre-foot of storage	108	131	95	86
Cost per acre-foot of net safe yield	760	860	690	710
Annual Costs				
Dam and reservoir	199,000	292,000	378,000	446,000
Cost per acre-foot of net safe yield	40	45	36	37
Cost per acre-foot of incremental net safe yield	--	62	22	45

Topatopa Dam and Reservoir. The Topatopa dam site is located on

Sespe Creek about 19 miles below the Cold Spring dam site, and is in Section 36, Township 6 North, Range 20 West, S.B.B. & M. Stream bed elevation at the site is about 2,100 feet, U.S.G.S. datum. Consideration was given to the construction of a dam and reservoir at the Topatopa site for storage of flood waters in Sespe Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The drainage area of Sespe Creek above the Topatopa dam site comprises about 171 square miles, and produced an estimated average seasonal runoff during the base period of about 43,600 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 37,600 acre-feet per season during the base period with the present pattern of land use and water supply development.

The Topatopa dam site and reservoir area were surveyed in 1950 by Fairchild Aerial Surveys, Inc., using photogrammetric methods, for the Ventura County Flood Control District, Zone 2. The dam site was mapped up to an elevation of 2,750 feet at a scale of one inch equals 100 feet, with a 5-foot contour interval. The reservoir area was mapped up to an elevation of 2,650 feet, at a scale of one inch equals 400 feet, with a contour interval of 20 feet. Storage capacities of Topatopa Reservoir at various stages of water surface elevation are given in Table 69.

TABLE 69.

## AREAS AND CAPACITIES OF TOPATOPA RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum, in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	2,100	0	0
20	2,120	5	50
40	2,140	17	270
60	2,160	35	780
80	2,180	61	1,740
100	2,200	90	3,250
120	2,220	120	5,310
140	2,240	150	7,950
160	2,260	180	11,200
180	2,280	220	15,200
200	2,300	270	20,000
220	2,320	320	25,900
240	2,340	370	32,900
260	2,360	430	40,900
280	2,380	510	50,300
300	2,400	580	61,200
320	2,420	650	73,500
322	2,422	660	75,000
340	2,440	730	87,300
355	2,455	790	100,000
360	2,460	810	102,600
380	2,480	900	119,700
400	2,500	1,020	138,900
420	2,520	1,110	160,300
440	2,540	1,230	183,800
460	2,560	1,350	209,600
480	2,580	1,480	238,000
500	2,600	1,590	268,700
520	2,620	1,720	301,800
540	2,640	1,850	337,500
550	2,650	1,920	356,300



Geologic investigation indicates that the Topatopa dam site is suitable for almost any type of structure up to heights above stream bed of the order of 400 feet. The geology of the site was studied by the Division of Water Resources during the current investigation. Previous geologic studies had been made by Dr. Charles P. Berkey, Paul F. Kerr, and Hyde Forbes, and by geologists of the Division of Water Resources in connection with the preparation of Division of Water Resources Bulletin No. 46. Some geologic work at the site has also been done by Thomas L. Bailey, Consulting Geologist. Three core holes were drilled at the Topatopa dam site in 1948 by the Ventura County Flood Control District totaling 302 feet in length. In 1952, 17 core holes were drilled by the United Water Conservation District, with a total length of 1,471 feet.

Rock exposed at the Topatopa dam site consists of hard, greenish-grey sandstone, interbedded with subordinate amounts of hard black or sandy shale. The sandstone beds vary from very massive to moderately thin bedded. The sandstone generally takes on a mottled appearance on weathering, and ripple-marked beds are present on both abutments just above the channel section. Strike of the bedding is across the channel and is quite consistent, averaging about north 30 degrees east. The dip is also uniform and averages about 18 degrees in a south-east direction, or downstream.

No positive evidence of a fault down the channel at the axis of the Topatopa dam has been found. However, a calcite deposit found in one of the drill holes of the United Water Conservation District suggest that a fault may exist in the channel at the point of drill hole No. 13. A fault was reported by Berkey and Kerr on the left abutment between about 0.25 and 0.5 mile upstream from the axis in a ravine containing a dry weather spring. The dip of the beds on either side of this fault varies from 30 degrees north on one side to 50 degrees south on the other, with gouge and calcite veins present between. This fault is now believed to extend along the left abutment downstream at an elevation of about 750 feet above the stream bed. It appears that the fault finally

approaches the stream bed and crosses it immediately above the confluence of Sespe and Alder Creeks. Two minor faults were noted on the left abutment, one of which dips steeply upstream and shows a displacement of about 20 feet, and the other which appears to be a small thrust. Another minor fault was noted in the right abutment. Three sets of joints occur at the axis of the dam, and probably persist through the area of the site.

The right abutment of the Topatopa dam site has very steep rugged walls for the first 200 feet above the stream bed, and then slightly gentler slope with a blocky uneven surface. The rock is strongly jointed, with joints somewhat open near the surface. As a result of the drilling program of the United Water Conservation District, it was determined that sound rock in the channel section lies beneath about 40 feet of sand, silt, gravel, and boulders of sandstone and crystalline rock. The first 150 feet above stream bed on the left abutment consists of a nearly vertical cliff, with a talus deposit to an elevation about 50 feet above the base of the cliff at the dam axis. Above the cliff the slope of the abutment is slightly gentler. The entire abutment is strongly jointed, including some closely spaced sets. Borrow pit exploration for impervious material for a possible earth filled dam at the Topatopa site was conducted by the Division of Water Resources in 1951, using a bulldozer to expose an area located about one mile upstream from the site. Tests of nine samples from this area showed the material to be suitable for the impervious section of an earth filled dam. The United Water Conservation District explored the same area in 1952, and another area at a closer location to the dam site, by drilling auger holes. Drilling indicated that approximately 6,700,000 cubic yards of impervious material were available within one mile upstream from the site. Pervious material for a fill-type dam was determined to be quite limited.

Records of runoff at the Topatopa dam site are not available.

However, estimates of runoff were made for the base period, utilizing the short record at the U.S.G.S. stream gaging station on Sespe Creek near Wheeler Springs, and the longer record at the U.S.G.S. station on Sespe Creek near Fillmore. Due to the generally easterly course of Sespe Creek above the dam site, it was assumed that the runoff characteristics would be similar to those at the similarly situated Cold Spring dam site. For this reason, the method of estimating runoff described for Cold Spring Reservoir was employed for the Topatopa site. To derive seasonal runoff at Topatopa Dam, estimated or measured seasonal runoff at the Wheeler Springs stream gaging station was increased by 242 per cent, or in proportion to the ratio of the respective drainage areas. Table 70 presents the estimated monthly runoff of Sespe Creek at the Topatopa dam site during the base period.



TABLE 70

## ESTIMATED MONTHLY RUNOFF OF SESPE CREEK AT TOPATOPA DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1936-37	1,300	290	6,430	4,900	27,800	22,740	6,770	2,460	1,170	520	340	260	74,980
1937-38	310	410	2,020	1,110	35,720	68,560	7,200	3,810	2,050	1,220	730	650	123,790
1938-39	260	290	1,940	1,710	1,040	2,280	800	440	260	130	100	650	9,900
1939-40	180	160	180	570	2,670	930	570	260	130	50	50	50	5,800
1940-41	290	260	12,080	22,920	68,430	85,150	45,970	11,510	4,870	2,640	1,690	1,270	257,080
1941-42	390	410	2,020	1,140	730	750	1,970	650	290	130	100	80	8,660
1942-43	180	260	340	25,520	16,910	23,520	3,630	1,790	960	540	360	260	74,270
1943-44	260	340	3,160	1,870	14,650	23,750	5,830	2,520	1,430	730	440	310	55,290
1944-45	210	1,560	490	390	4,980	2,520	1,320	540	310	160	130	80	12,690
1945-46	130	210	4,410	730	750	4,850	3,600	780	290	160	100	80	16,090
1946-47	80	2,410	3,960	1,190	590	490	360	210	130	80	50	50	9,600
1947-48	50	50	80	80	130	290	310	160	80	30	30	30	1,320
1948-49	30	60	140	170	150	480	320	250	90	30	20	10	1,750
1949-50	20	60	310	310	660	370	370	190	90	20	10	10	2,420
1950-51	10	20	50	120	130	200	140	120	30	10	0	0	830

Average seasonal runoff, 1936-37 through 1950-51

43,630

Based on the estimates of runoff, monthly studies of operation of Topatopa Reservoir during the base period were made for three sizes of reservoir, of 50,000 acre-foot, 75,000 acre-foot, and 100,000 acre-foot storage capacity, under both the uniform release and rapid release methods of operation. In all of the studies, an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 8,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 1.70 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies.

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.15	April	0.15
November	0.06	May	0.19
December	0.04	June	0.21
January	0.04	July	0.25
February	0.05	August	0.25
March	0.10	September	0.21
		TOTAL	1.70

The estimated values of net safe seasonal yield that would be obtained under both the uniform release and rapid release operating criteria are presented in Table 71. The relationship between reservoir storage capacity and net safe seasonal yield, with Topatopa Reservoir operated by the uniform release method with releases for maintenance of water levels in Fillmore and Santa Paula Basins, is depicted graphically on Plate 36.

TABLE 71  
ESTIMATED NET SAFE SEASONAL YIELDS OF TOPATOPA RESERVOIR  
(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : with releases : for maintenance of : ground water levels :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : without releases : for maintenance of : ground water levels :	Available to Oxnard : Forebay, Oxnard : Santa Clara River : Hydrologic Unit : Plain, and Pleasant : Valley Subunits :	Available to Oxnard : Forebay, Oxnard : Santa Clara River : Hydrologic Unit : Plain, and Pleasant : Valley Subunits :
50,000	8,000	8,400	8,100	6,000
75,000	12,400	12,900	12,500	9,000
100,000	16,500	17,000	16,700	12,000

As a result of the geologic investigation, yield studies, and reconnaissance type estimates of cost of dams of various heights and types, it was concluded that the most economical type of dam at the Topatopa site would be concrete arch, with a maximum physical limit in height of about 400 feet above stream bed. To determine the variation in cost with height of dam, and the accomplishments of reservoirs created by various heights of dam, estimates of cost were prepared for concrete arch dams 280 feet, 322 feet, and 355 feet in height from stream bed to top of spillway gates, creating reservoirs with storage capacities of 50,000 acre-feet, 75,000 acre-feet, and 100,000 acre feet, respectively. The dams would be concrete arches, of the variable radius and variable angle type, and would be located so as to best fit the topography at the site.

In the cost estimates, it was assumed that a depth of about 40 feet of sand, gravel, and boulders would be stripped in the channel section. On the right abutment, it was assumed that a depth of about 25 feet of jointed rock would be stripped for the first 200 feet above the stream bed, and that above this elevation the depth of stripping would be about 35 feet. It was assumed that on the left abutment, a depth of about 18 feet of rock would be stripped for the lowermost 200 feet in elevation above stream bed, and that above this elevation the stripping depth would be about 35 feet. Water testing of several of the core holes drilled by United Water Conservation District indicated that moderate to heavy grouting of the foundation would be necessary. For cost estimating purposes, it was assumed that a concrete batch plant would be placed in the vicinity of the dam site during construction. Concrete aggregates could be made locally from a granite deposit located about three miles upstream.

Spillways, for all heights of dam considered, would have a discharge capacity of 82,000 second-feet, which is the estimated peak discharge of a once in 1,000-year flood. For each of the three sizes of dam, two spillways were incorporated in the design. A primary spillway would be provided along the extreme



right end of the dam. together with a secondary spillway formed by a notch in the center of the dam. The primary spillway would be equipped with three tainter gates, each 30 feet in length and 20 feet in height. With the water level in the reservoir at the lip of the notched spillway and at the top of the gates, the gated spillway was designed to discharge 28,000 second-feet. With an additional depth of water of 10 feet, the gated spillway would discharge 52,000 second-feet, and the notched spillway 30,000 second-feet. A residual freeboard of 5 feet was provided above this maximum water surface elevation. No provision was made for cushioning of the stream bed, below the notched spillway, as such spill would be very infrequent. The primary spillway would consist of an ogee weir, with the aforementioned gates, and a concrete lined chute discharging into Sespe Creek about 400 feet downstream from the dam. The design of the primary spillway included a concrete gravity thrust block on its left side, separating the spillway weir from the arch. This thrust block would also act as the left training wall for spillway discharge.

Outlet works would include a 60-inch diameter steel pipe, placed through the dam near the right abutment at an elevation of 2160 feet. Discharge from the reservoir would be controlled by a high pressure slide gate, 4.5 feet by 4.5 feet in dimensions, on the upstream face of the dam. Releases would also be controlled at the downstream end of the outlet pipe by a 54-inch diameter Howell-Bunger valve. A trash rack structure would be placed at the upstream end of the outlet pipe. It was estimated that construction of the dam of 280 foot height would require about two years, that of 322 foot height, two and one-half years, and the dam of 355 foot height, about three years. Diversion of the stream during construction would be accomplished by means of a flume or pipe, with the aid of a small coffer dam. Winter flood flows could be passed over a depressed section of the concrete dam.

It was estimated that between 510 and 790 acres of minor clearing would be required in the reservoir area, depending on the height of dam to be constructed. The Topatopa dam site and most of the reservoir lands are federally owned, and in the Los Padres National Forest. In 1952, the cost of acquisition of private lands in the reservoir area was estimated by the Ventura County Flood Control District to be about \$25,000 for the two smaller dams, and about \$62,500 for the larger dam. An all weather access road approximately 10.5 miles in length would be required before construction could start. The United Water Conservation District estimated in 1952 that this road would cost about \$400,000.

Presented in Table 72 are pertinent data with respect to the general features of the three sizes of dams and reservoirs considered at the Topatopa site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 100,000 acre-feet are shown on Plate 29, entitled "Topatopa Dam on Sespe Creek."

TABLE 72

GENERAL FEATURES OF THREE SIZES OF DAM AND RESERVOIR AT THE  
TOPATOPA SITE ON SESPE CREEK

<b>Concrete Arch Dam</b>			
Crest elevation, in feet, U.S.G.S. datum . . . . .	2,395	2,437	2,470
Crest length, in feet . . . . .	850	965	1,120
Crest width, in feet. . . . .	9	10	10
Height of dam, to top of spillway gates above stream bed, in feet . . . . .	280	322	355
Freeboard, above top of spillway gates, in feet . . . . .	15	15	15
Elevation of stream bed, in feet, U.S.G.S. datum. . . . .	2,100	2,100	2,100
Volume of concrete in dam, in cubic yards. . . . .	287,000	412,000	522,000
<b>Reservoir</b>			
Surface area at top of spillway gates, in acres. . . . .	510	656	788
Gross storage capacity, at top of spillway gates, in acre-feet. . . . .	50,000	75,000	100,000
Type of spillways . . . . .	Notched overpour, and ogee weir with gates and concrete lined chute	Notched overpour, and ogee weir with gates and concrete lined chute	Notched overpour, and ogee weir with gates and concrete lined chute
Spillway discharge capacity, in second- feet . . . . .	82,000	82,000	82,000
Type of outlet. . . . .	60-inch dia- meter steel pipe, through dam	60-inch dia- meter steel pipe, through dam	60-inch dia- meter steel pipe, through dam



Presented in Table 73 is a summary comparison of capital and annual costs of the three considered sizes of dam and reservoir at the Topatopa site. Also presented in Table 73 are estimated unit costs of storage capacity and net safe yields of water that would be developed by construction of the three sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation. Certain of the relationships presented in Table 73 are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the three sizes of dam and reservoir at the Topatopa site are included in Appendix C.

TABLE 73

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF  
WATER AT THE TOPATOPA SITE ON SESPE CREEK

Item	Reservoir storage capacity, in acre-feet		
	50,000	75,000	100,000
Capital Costs			
Dam and reservoir	\$ 9,155,000	\$ 12,520,000	\$ 15,540,000
Cost per acre-foot of storage	183	167	155
Cost per acre-foot of net safe yield	1,140	1,010	940
Annual Costs			
Dam and reservoir	482,000	652,000	805,000
Cost per acre-foot of net safe yield	60	53	49
Cost per acre-foot of incremental net safe yield	---	39	37

Hammel Dam and Reservoir. The Hammel dam site is located on the

lower reaches of Sespe Creek, in Section 2, Township 4 North, Range 20 West, S.B.B. & M. The site is about four miles north and one mile west of the town of Fillmore, and about seven miles upstream from the confluence of Sespe Creek with the Santa Clara River. Stream bed elevation at the site is about 790 feet, U.S.G.S. datum. Consideration was given to the construction of a dam and reservoir at the Hammel site for storage of flood waters in Sespe Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunitsof the Santa Clara River Hydrologic Unit.

The drainage area of Sespe Creek above the Hammel dam site comprises about 246 square miles, and produced an estimated average seasonal runoff during the base period of about 92,000 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 73,600 acre-feet per season during the base period with the present pattern of land use and water supply development.

The Hammel dam site and reservoir area were surveyed in 1950 by Fairchild Aerial Surveys, Inc. using aerial photogrammetric methods, for the Ventura County Flood Control District, Zone 2. The dam site was mapped up to an elevation of 1,325 feet, at a scale of one inch equals 100 feet, with a 5-foot contour interval. The reservoir area was mapped at a scale of one inch equals 400 feet, with a contour interval of 20 feet. Storage capacities of Hammel Reservoir at various stages of water surface elevation are given in Table 74.

TABLE 74

## AREAS AND CAPACITIES OF HAMMEL RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum, in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	790	0	0
60	850	6	180
70	860	11	270
80	870	17	405
90	880	22	600
100	890	27	845
110	900	32	1,140
120	910	38	1,490
130	920	45	1,910
140	930	51	2,390
150	940	58	2,930
160	950	64	3,540
170	960	71	4,210
180	970	77	4,960
190	980	84	5,770
200	990	91	6,640
210	1,000	98	7,590
220	1,010	110	8,610
230	1,020	115	9,700
240	1,030	120	10,900
250	1,040	130	12,100
260	1,050	140	13,400
270	1,060	145	14,800
280	1,070	155	16,300
290	1,080	160	17,900
300	1,090	170	19,600
310	1,100	180	21,400
320	1,110	190	23,300
330	1,120	200	25,000
340	1,130	210	27,300
350	1,140	220	29,400
360	1,150	230	31,700
370	1,160	240	34,000
380	1,170	250	36,500
390	1,180	260	39,000
400	1,190	270	41,700
410	1,200	285	44,500
420	1,210	300	47,400
428	1,218	308	50,000
430	1,220	310	50,400
440	1,230	325	53,600
450	1,240	340	56,900
460	1,250	350	60,400
470	1,260	365	63,900
480	1,270	380	67,700
490	1,280	390	71,500
500	1,290	410	75,500
510	1,300	420	79,700



Based upon preliminary geological reconnaissance, the Hammel dam site appears suitable for a moderately high masonry structure. No prior geologic work at this site is known, nor has it been drilled. The dam site is located on the southerly limb of the Coldwater anticline, a distinct structural feature in both Coldwater and Sespe formations. The underlying Coldwater sandstone is exposed upstream from the dam site along the anticline, while the Sespe formation is the only rock exposed in the vicinity of the axis. The beds dip steeply downstream about 60 degrees south, and strike across the channel about north 65 degrees east.

The Sespe formation at the Hammel site is a medium to coarse grained, reddish brown, bedded sandstone, generally well indurated. Bedding planes and color banding in the various beds are noteworthy. There are relatively few joints and fractures, but one discontinuous open fracture parallels the left abutment in its lower third near the channel section at the axis. No serious structural defects were noted in this area. The harder beds of sandstone forming the abutments are several hundreds of feet in stratigraphic thickness, and have formed a narrow "V"-shaped canyon with slopes averaging steeper than 1:1 in the lower 300 feet of the cross section at the dam site.

The right abutment in the lower portion, to an elevation about 50 feet above stream bed, has talus blocks up to 50 feet in diameter. Average depth of talus in this area is 20 feet. Above the talus, the right abutment has a light cover of soil and talus over moderately jointed rock. In the channel section, about 120 feet in width, there is a filling of gravels, boulders, and blocks up to 30 feet in diameter. No signs of faulting or pronounced shears were noted in the channel section. A nearly vertical bare cliff rises about 250 feet above stream bed on the left abutment, with good quality rock exposed. Above the top of this cliff the exposed rock exhibits more pronounced jointing. The left abutment appears more favorable topographically for appurtenant features such as outlet tunnels. The canyon is narrow and appurtenant structures may

be in a hazardous position due to the possibility of large blocks sliding into the canyon.

Records of runoff at the Hammel dam site are not available. However, runoff at the site was estimated equal to 97 per cent of the measured runoff at the U.S.G.S. stream gaging station on Sespe Creek near Fillmore, adjusted for diversions made upstream from the gaging station by the Fillmore Irrigation Company. The estimates were based on the ratio of watershed areas above the dam site and gaging station, weighted by estimated mean precipitation on the respective areas. The estimated monthly runoff of Sespe Creek at the Hammel dam site during the base period is presented in Table 75.

## ESTIMATED MONTHLY RUNOFF OF SESPE CREEK AT HAMMEL DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	Oct. :	Nov. :	Dec. :	Jan. :	Feb. :	Mar. :	Apr. :	May :	June :	July :	Aug. :	Sept. :	Total
1936-37	2,870	630	14,220	10,830	61,540	50,330	15,000	5,440	2,610	1,140	750	560	165,920
1937-38	580	760	3,780	2,100	66,880	128,360	13,480	7,140	3,820	2,270	1,360	1,220	231,750
1938-39	1,210	1,320	8,820	7,730	4,670	10,310	3,660	1,990	1,130	590	420	2,940	44,790
1939-40	970	870	1,030	3,090	14,460	5,020	3,070	1,470	650	340	280	260	31,510
1940-41	390	380	17,130	32,490	96,980	120,670	65,140	16,300	6,920	3,750	2,390	1,790	364,330
1941-42	1,810	1,940	9,550	5,410	3,450	3,550	9,390	3,020	1,370	630	440	410	40,970
1942-43	420	560	730	56,820	37,660	52,380	8,060	3,990	2,160	1,200	800	600	165,380
1943-44	650	820	7,940	4,710	36,810	59,650	14,650	6,340	3,560	1,840	1,080	790	138,840
1944-45	890	6,430	2,040	1,670	20,640	10,410	5,490	2,300	1,300	680	500	370	52,720
1945-46	480	770	17,190	2,800	2,950	18,850	14,050	3,030	1,130	560	380	320	62,510
1946-47	390	10,970	18,090	5,430	2,760	2,290	1,680	950	560	310	280	260	43,970
1947-48	290	290	460	510	800	1,680	1,820	960	480	210	180	160	7,840
1948-49	200	230	520	710	720	3,680	1,280	700	310	170	160	140	8,820
1949-50	170	420	1,770	3,230	5,780	1,620	1,750	770	330	200	160	190	16,390
1950-51	190	240	250	360	440	710	500	320	150	100	80	100	3,440
Average seasonal runoff, 1936-37 through 1950-51.													91,950



Based on the estimates of runoff, monthly studies of operation of Hammel Reservoir during the base period were made for two sizes of reservoir, of 25,000 acre-foot and 50,000 acre-foot storage capacity, under both the uniform release and rapid release methods of operation. In all of the studies, an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 12,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 1.70 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies.

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.15	April	0.15
November	0.06	May	0.19
December	0.04	June	0.21
January	0.04	July	0.25
February	0.05	August	0.25
March	0.10	September	<u>0.21</u>
		TOTAL	1.70

The estimated values of net safe seasonal yield that would be obtained under both the uniform release and rapid release operating criteria are presented in Table 76. The relationship between reservoir storage capacity and net safe seasonal yield, with Hammel Reservoir operated by the uniform release method, with releases for maintenance of ground water levels in Fillmore and Santa Paula Basins, is depicted graphically on Plate 36.

TABLE 76

## ESTIMATED NET SAFE SEASONAL YIELDS OF HAMMEL RESERVOIR

(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	: Available to Oxnard	: Available to Oxnard	:	:
	: Forebay, Oxnard	: Forebay, Oxnard	:	: Available to Oxnard
	: Plain and Pleasant	: Plain, and Pleasant	: Available within	: Forebay, Oxnard
	: Valley Subunits,	: Valley Subunits,	: Santa Clara River	: Plain, and Pleasant
	: with releases	: without releases	: Hydrologic Unit	: Valley Subunits
	: for maintenance of	: for maintenance of	:	:
	: ground water levels	: ground water levels	:	:
25,000	4,000	5,800	4,100	3,000
50,000	9,500	11,300	9,600	8,000

As a result of the geological investigation and the reservoir yield studies, estimates of cost were prepared for two dams at the Hammel site with heights of 330 feet and 428 feet from stream bed to top of spillway gates, creating reservoir storage capacities of 25,000 and 50,000 acre-feet, respectively. For both dams, a concrete gravity structure was contemplated. The dams would have crest widths of 30 feet, 0.8:1 downstream slopes and 0.05:1 upstream slopes, except that the upstream slope for the higher dam would be 0.5:1 below an elevation of 823 feet. The two dams would have crest lengths of 470 feet and 810 feet, respectively.

In the cost estimates, it was assumed that the talus and a depth of about 15 feet of jointed rock would be stripped from the right abutment up to an elevation about 75 feet above stream bed. Above this elevation, about 3 feet of soil and talus and 30 feet of rock would be removed. In the channel section, a depth of about 25 feet of gravel, boulders, and blocks up to 30 feet in diameter, would have to be removed. It was assumed that a cut would be made in the cliff which forms the lower portion of the right abutment. The cut would be about 15 feet in depth in its lower half, and about 25 feet in depth in the upper half. Above the top of the cliff, approximately 250 feet above stream bed, the cut would be increased in depth to about 30 feet to include removal of weathered surficial materials.

Spillways, for both heights of dam considered, would have a discharge capacity of 90,000 second-feet, which is the estimated peak discharge of a one in 1000-year flood. The spillways would consist of a concrete overpour section in the center of the dam, and would be provided with four tainter gates, each 30 feet high and 40 feet wide. Maximum depth of water above the bottom of the gates would be 30 feet, and an additional 5 feet of freeboard would be provided. A spillway bucket would be provided at the downstream toe of the dam to deflect the high velocity flood flows into the air. A roadway, 10 feet in width, would be located on the crest of the dams and across the spillway near the upstream face, for access to the tainter gate controls.

Water would be released from the reservoir into a 54-inch diameter steel outlet pipe, located through the dam near the left abutment at an elevation of approximately 910 feet. The outlet pipe lengths would be 180 feet and 250 feet for the lower and higher dams, respectively. Releases would be controlled by a 18-inch diameter needle valve and a high pressure ring seal gate. A 54-inch diameter sluiceway pipe would be provided through the center of the dam at an elevation of 800 feet. The sluice pipe would be 310 feet in length for the lower dam and 400 feet in length for the higher dam, and would be controlled by two high pressure ring seal gates. Steel trashrack structures would be provided at the upstream ends of the outlet and sluice pipes, and access to the controls would be through chambers provided in the dam.

It was estimated that construction of a dam, either of 330 or 428 foot height, at the Hammel site would require about two years. Diversion of summer and small winter stream flows during construction would be through a 7-foot diameter concrete lined tunnel of horseshoe section located through the left abutment. Major floods would pass over a depressed section of the concrete dam. The diversion tunnel would be about 490 feet in length for the



lower dam and about 560 feet in length for the higher dam. Following construction, the tunnel would be plugged at the upstream end.

Aggregate for a concrete dam could be imported to the Hammel site by truck or rail. Rail haul to within about five miles of the site is available. The aggregate could come from sources along the Santa Clara River area from 7 to 20 miles distant. After suitable testing, it might be determined that rock near the dam site is usable after crushing and screening.

It was estimated that from 20 to 320 acres of clearing would be required in the reservoir area, depending on the height of dam to be constructed. There are no improvements in the area. Approximately 170 acres are under private ownership, while the remainder of the property belongs to the Federal Government. In 1952, the cost of acquisition of private lands in the reservoir area was estimated by the Ventura County Flood Control District to be about \$12,500 for both sizes of dam. Construction of an access road, approximately 2 miles in length, would be required before construction could start.

Presented in Table 77 are pertinent data with respect to the general features of the two sizes of dams and reservoirs considered at the Hammel site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 50,000 acre-feet are shown on Plate 30, entitled "Hammel Dam on Sespe Creek".

TABLE 77

GENERAL FEATURES OF TWO SIZES OF DAM AND RESERVOIR  
AT THE HAMMEL SITE ON SESPE CREEK

---

Concrete Gravity Dam

Crest elevation, in feet, U.S.G.S. datum . . . . .	1,125	1,223
Crest length, in feet . . .	470	810
Crest width, in feet. . . .	30	30
Height of dam, to top of spillway gates above stream bed, in feet. . . .	330	428
Freeboard, above top of spillway gates, in feet. . .	5	5
Elevation of stream bed, in feet, U.S.G.S. datum. .	790	790
Volume of concrete in dam, in cubic yards . . . . .	530,700	1,067,900

Reservoir

Surface area, at top of spillway gates, in acres .	200	308
Gross storage capacity, at top of spillway gates, in acre-feet . . . . .	25,000	50,000
Type of spillway. . . . .	Overpour, with gates and bucket	Overpour, with gates and bucket
Spillway discharge capa- city, in second-feet . . .	90,000	90,000
Type of outlets . . . . .	54-inch diameter steel pipe through dam, and 54-inch diameter steel pipe sluiceway	54-inch diameter steel pipe through dam, and 54-inch diameter steel pipe sluiceway

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Presented in Table 78 is a summary comparison of capital and annual costs of the two considered sizes of dam and reservoir at the Hammel site. Also presented in Table 78 are estimated unit costs of storage capacity and net safe yields of water that would be developed by construction of the two sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. Certain of the relationships presented in Table 78 are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the two sizes of dam and reservoir at the Hammel site are included in Appendix C.

TABLE 78

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF WATER  
AT THE HAMMEL SITE ON SESPE CREEK

Item	Reservoir storage capacity, in acre-feet	
	25,000	50,000
Capital Costs		
Dam and reservoir	\$12,890,000	\$24,490,000
Cost per acre-foot of storage	516	490
Cost per acre-foot of net safe yield	3,220	2,580
Annual Costs		
Dam and reservoir	666,000	1,252,000
Cost per acre-foot of net safe yield	166	132
Cost per acre-foot of incremental net safe yield	---	107



Fillmore Dam and Reservoir. The Fillmore dam site, the lowermost of all sites considered on Sespe Creek, is located in Section 13, Township 4 North, Range 20 West, S.B.B. & M., about two miles north of the town of Fillmore and about 3.2 miles upstream from the confluence of Sespe Creek with the Santa Clara River. Stream bed elevation at the site is about 490 feet, U.S.G.S. datum. The location is such that practically complete regulation of the flow of Sespe Creek could be achieved through construction of a reservoir of sufficient size. Consideration was given to the construction of a dam and reservoir at the Fillmore site for storage of flood waters in Sespe Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The drainage area of Sespe Creek above the Fillmore dam site comprises about 259 square miles, and produced an estimated average seasonal runoff during the base period of about 96,700 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 77,400 acre-feet per season during the base period with the present pattern of land use and water supply development.

The Fillmore dam site was surveyed by the Ventura County Flood Control District in 1951, using instrumental methods. The map resulting from this survey is at a scale one inch equals 200 feet, with a contour interval of 2 feet on flat areas and gently sloping hill sides, and 25 feet on steep hill sides. The map extends up to an elevation of 850 feet on the right abutment and 800 feet on the left abutment. An area-capacity curve for Fillmore Reservoir, data for which were obtained from U.S.G.S. quadrangles, at a scale of 1:24,000, was provided by the Ventura County Flood Control District. Storage capacities of Fillmore Reservoir at various stages of water surface elevation taken from this curve, are given in Table 79.

TABLE 79

## AREAS AND CAPACITIES OF FILLMORE RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum, in feet	:	: Water surface area, in acres	:	: Storage capacity, in acre-feet
0	490		0		0
10	500		22		110
20	510		52		480
30	520		100		1,240
40	530		170		2,600
50	540		210		4,530
60	550		260		6,890
70	560		320		9,790
80	570		380		13,300
90	580		410		17,300
100	590		450		21,500
110	600		480		26,200
120	610		520		31,200
130	620		560		36,600
140	630		600		42,400
150	640		640		48,700
160	650		700		55,400
170	660		770		62,700
172	662		780		64,300
180	670		820		70,700
190	680		870		79,100
200	690		900		88,000
210	700		935		97,200
211	701		940		98,100
220	710		960		107,700
230	720		980		116,400
240	730		1,000		126,200
250	740		1,040		136,300
260	750		1,070		146,900
261	751		1,080		147,900
270	760		1,110		157,800
280	770		1,150		169,100
290	780		1,190		180,800
300	790		1,220		192,900
310	800		1,260		205,300

Based upon available geological information, including that resulting from reconnaissance examination and seismic surveys during the investigation, it was concluded that the only types of dam possible at the Fillmore site are earth-fill or rockfill structures. Furthermore, the construction of such types of dam would only be feasible if further tests of the stability of the right abutment should give necessary results.

Geology in the area of the Fillmore dam site has been mapped by Kew, Hoots, Eldridge for the oil industry, and the geology of the more recent water-bearing deposits was reported on by Gentry in Division of Water Resources Bulletin No. 46. Much detailed work has been done on the older rock formations since publication of the aforementioned papers, but little has been done with the more recent water-bearing materials.

Rocks exposed on the left abutment and in the left channel section a few hundred feet downstream from the axis of the dam are Miocene Modelo shales and siltstones, generally fine grained, thin bedded, and laced with slip or shear zones and gouge streaks. Material exposed over the wide gently sloping terrace between the shale and the right abutment appears to be old deposits of sand, gravel, and boulders, with a relatively thin soil cover. At the stream channel, a depth of from 15 to 20 feet of boulders and smaller fragments, and about 4 feet of overlying soil is visible at the edge of this terrace.

The right abutment, whose base is at an elevation about 100 feet above the stream bed, appears to be a portion or remnant of an old alluvial cone or terrace deposit, now considerably dissected. The materials comprising this abutment are generally unstratified, unsorted, and poorly consolidated. They consist of varying proportions of sandy and clayey material, containing rock fragments which vary in size to large subangular blocks. The upper surface of the abutment is relatively even and gently sloping, and supports a light brush and tree growth. The steep dissected side slopes have a heavy brush cover.



The San Cayetano thrust fault has been mapped by Kew and others, extending in a north-northwesterly direction near the center of the channel section at the Fillmore dam axis. The northeast limb of the fault is upthrown. If this mapping is correct, the Modelo shale of the left abutment does not extend to the west (right) of the fault, except at great depth.

Two 8-inch cable tool holes were drilled, and a seismic profile run by the Division of Water Resources to establish the presence or absence of the Modelo shale at shallow depths on the low right abutment terrace, and, if the shale was found to be absent, to determine whether other impervious materials suitable for a dam foundation were present. One hole was located on the sloping terrace near the base of the right abutment at an elevation about 35 feet above stream bed, and the other in the lower part of the sloping terrace at a site about 350 feet from the edge of the channel section, at an elevation about 20 feet above stream bed. The hole near the right abutment was drilled to a 60-foot depth, and the lower hole to a 67-foot depth. Neither of these holes encountered shale or comparable material, nor did they strike water table. They did, however, strike fairly tight silt and silty clay, commonly containing sand and pebbles, almost continuously from a few feet below the surface to the bottom of the holes. This material is apparently terrace material similar to that composing the right abutment.

Seismic profiles were run by the Division of Water Resources, from the shale exposed in the channel section upstream to the axis, where the shale is under the gravels, and thence along the axis of the dam toward the right abutment as far as Grand Avenue. Another profile was run a short distance along Grand Avenue both upstream and downstream from the axis. This survey indicated the seismic velocity in the shale at the ground surface to be about 6,000 feet per second. Materials with velocity up to 7,000 feet per second (probably saturated shale) were found underlying the gravels of the active channel section. Material of

similar velocity was found to extend to Grand Avenue along the profile line, but at increasingly greater depths. Depths varied from zero in the channel section to about 100 feet at the hole in the lower terrace, and 200 feet at the intersection of the axis and Grand Avenue. This material may be saturated tight terrace material similar to that encountered in the drill holes. There are indications that this high velocity material may be pitching off in a downstream direction. A material having still higher velocity, on the order of 11,000 feet per second, was picked up toward the right abutment from the stream channel. This appears to have the seismic velocity of a consolidated sandstone, and may represent a small portion or fault sliver of Pico sandstone such as is exposed at the surface about a mile upstream.

About one-half mile downstream from the Fillmore dam site, an oil company has drilled through approximately 12,000 feet of more recent sediments without encountering the Modelo shale. Evidence from this well, from the shallow drill holes on the axis of the dam, and from the seismic profiles indicates that the mapped location of the San Cayetano thrust fault in the channel section near the left abutment is correct, and that there is little chance of finding the Modelo shale at any reasonable depth at the dam site to the right of the fault.

Records of runoff at the Fillmore dam site are not available. However, runoff at the site was estimated as equal to 102 per cent of the measured runoff at the U.S.G.S. stream gaging station on Sespe Creek near Fillmore, adjusted for diversions made upstream from the gaging station by the Fillmore Irrigation Company. The estimates were based on the ratio of respective watershed areas above the dam site and gaging station. The estimated monthly runoff of Sespe Creek at the Fillmore dam site during the base period is presented in Table 80.

## ESTIMATED MONTHLY RUNOFF OF SESPE CREEK AT FILLMORE DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	: Oct. :	Nov. :	Dec. :	Jan. :	Feb. :	Mar. :	Apr. :	May :	June :	July :	Aug. :	Sept. :	Total
1936-37	3,020	660	14,950	11,390	64,710	52,930	15,750	5,720	2,740	1,200	790	590	174,450
1937-38	610	790	3,980	2,210	70,330	134,980	14,180	7,510	4,020	2,390	1,430	1,290	243,720
1938-39	1,280	1,390	9,270	8,130	4,920	10,840	3,850	2,090	1,190	620	440	3,090	47,110
1939-40	1,020	920	1,090	3,250	15,210	5,280	3,230	1,550	680	350	300	270	33,150
1940-41	410	400	18,010	34,170	101,980	126,890	68,490	17,140	7,270	3,950	2,520	1,890	383,120
1941-42	1,910	2,040	10,050	5,690	3,630	3,730	9,870	3,170	1,440	660	460	430	43,080
1942-43	440	590	770	59,750	39,600	55,080	8,480	4,190	2,280	1,260	840	630	173,910
1943-44	680	860	8,350	4,950	38,710	62,720	15,400	6,670	3,740	1,940	1,130	830	145,980
1944-45	940	6,760	2,140	1,750	21,710	10,940	5,770	2,420	1,370	720	520	390	55,430
1945-46	510	800	18,070	2,950	3,100	19,820	14,780	3,180	1,190	590	400	340	65,730
1946-47	410	11,540	19,020	5,710	2,910	2,410	1,760	990	590	330	290	280	46,240
1947-48	300	310	490	530	840	1,770	1,920	1,010	510	220	190	170	8,260
1948-49	210	240	540	740	760	3,870	1,340	740	330	180	160	140	9,250
1949-50	180	440	1,860	3,390	6,080	1,700	1,830	810	350	210	170	200	17,220
1950-51	200	250	260	370	460	740	520	340	150	100	90	100	3,580
Average seasonal runoff, 1936-37 through 1950-51													96,680



Based on the estimates of runoff, monthly studies of operation of Fillmore Reservoir during the base period were made for three sizes of reservoir, of 64,000 acre-feet, 98,000 acre-feet, and 148,000 acre-feet storage capacity, under both the uniform release and rapid release methods of operation. In all of the studies, an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 12,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 1.70 feet, distributed in accordance with the following tabulation, was employed in the operation studies.

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.15	April	0.15
November	0.06	May	0.19
December	0.04	June	0.21
January	0.04	July	0.25
February	0.05	August	0.25
March	0.10	September	<u>0.21</u>
		TOTAL	1.70

The estimated values of net safe seasonal yield that would be obtained under both the uniform release and rapid release operating criteria are presented in Table 81. The relationship between reservoir storage capacity and net safe seasonal yield, with Fillmore Reservoir operated by the uniform release method with releases for maintenance of water levels in Fillmore and Santa Paula Basins, is depicted graphically on Plate 36.

TABLE 81  
ESTIMATED NET SAFE SEASONAL YIELDS OF FILLMORE RESERVOIR  
(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : with releases : for maintenance of : ground water levels:	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : without releases : for maintenance of : ground water levels:	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits : Available within : Santa Clara River : Hydrologic Unit : :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits : :
64,000	12,500	15,000	12,700	10,500
98,000	20,000	24,000	20,300	13,500
148,000	27,000	32,000	27,500	16,000

Although the Fillmore reservoir site affords an opportunity for the greatest degree of control of runoff from the Sespe Creek watershed, to achieve such control an earth or rock fill dam of considerable length would be required. Since suitable foundation material was not encountered at moderate depths, it was concluded that to extend the impervious section of a suitable dam to the underlying shale bedrock would not be feasible. Any structure contemplated at the Fillmore dam site would necessarily be floated on the terrace material overlying bedrock, using a shallow and narrow cutoff to reduce underflow. The high degree of development prevailing in the Fillmore Reservoir area would make acquisition of the necessary lands very expensive. For these reasons, it was concluded that construction of a dam and reservoir at the Fillmore site is not feasible at the present time. Therefore, design of the dam and appurtenant features, and estimates of costs, were limited to those of a reconnaissance nature necessarily made to arrive at the foregoing conclusion.

Reconnaissance type cost estimates were prepared for three earth-fill dams at the Fillmore site with heights of 172 feet, 211 feet, and 261 feet from stream bed to spillway lip, creating reservoir storage capacities of 64,000 acre-feet, 98,000 acre-feet, and 148,000 acre-feet, respectively. For all heights of dam a rolled fill structure was contemplated, with upstream and

downstream slopes of 3:1, and a crest width of 30 feet. An open cut spillway, including an ogee weir section and a concrete lined chute, could be constructed across the left abutment. The cost estimates were based upon a freeboard of 10 feet from spillway lip to crest of dam.

A depth of about 5 feet of weathered material in the root zone should be stripped from the right abutment under the impervious section of an earthen dam. Depths of 5 to 10 feet of terraced material should be similarly stripped from the right side terrace. Gravel and boulders to a depth of 10 feet should be removed under the impervious section from the active channel, about 60 feet in width, and a depth of about 5 feet of weathered shale and siltstone should be removed from this vicinity where it is exposed. Practically all excavated materials could be salvaged. A depth of about 12 feet of boulders and gravel should be stripped under the impervious section from the low terrace on the left abutment, plus about 2 feet of fractured shale beneath these gravels and boulders. The bouldery fill should be similarly stripped from the upper terrace to a depth of about 20 feet. At least 70 per cent of this material would be recoverable for impervious section.

Materials taken from the terrace deposit upstream from the right abutment appear to be the main source of materials for an impervious section near the Fillmore dam site. About one-third of this material would have to be screened to eliminate the boulders and large blocks, which could then be salvaged for blanket material. Compaction and permeability tests indicated that careful selection, and possible blending of materials, would be necessary to construct a suitable impervious fill from the terrace deposit. In addition to the material of the right abutment, it is possible that the soil and underlying sediments of the low terrace between the right abutment and the channel section might be usable. Also, the material of the upstream terrace on the left abutment appears to be similar to that tested from the right abutment, and should be usable. Removal



of trees, stumps, and roots might present a problem as to the suitability of this material. Previous fill material is available in limited quantities in the channel of Sespe Creek both upstream and downstream from the axis of the dam, and large quantities of similar material could be obtained from the Santa Clara River channel about three miles downstream. The nearest heavy rock or riprap material available appear to be hard red Sespe sandstone located about three miles upstream near the Hammel Dam site.

The Fillmore reservoir area, to a distance of about 1.5 miles upstream from the dam site, contains several hundred acres of mature orange groves and suburban residences, and a number of oil rights and leases. Two county roads would be flooded and depending on the size of dam, several existing oil wells might possibly be inundated. A preliminary appraisal report prepared by the Ventura County Flood Control District in September 1951, estimated that the fair market value of property that would have to be acquired for construction of Fillmore Dam and Reservoir was \$2,155,600.

Presented in Table 82 is a summary comparison of capital and annual costs of the three considered sizes of dam and reservoir at the Fillmore site. Also presented in Table 82 are estimated unit costs of storage capacity and net safe yields of water that would be developed by construction of the three sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. It is emphasized that the estimated costs are of a reconnaissance nature.

TABLE 82

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS  
OF WATER AT FILLMORE SITE ON SESPE CREEK

Item	Reservoir storage capacity,		
	in acre-feet		
	64,000	98,000	148,000
Capital Costs			
Dam and reservoir	\$18,966,000	\$28,352,000	\$44,680,000
Cost per acre-foot of storage	296	289	302
Cost per acre-foot of net safe yield	1,520	1,420	1,650
Annual Costs			
Dam and reservoir	968,000	1,445,000	2,273,000
Cost per acre-foot of net safe yield	77	72	84
Cost per acre-foot of incremental net safe yield	---	64	118

Upper Blue Point Dam and Reservoir. The Upper Blue Point dam site is located on Piru Creek in Section 10, Township 5 North, Range 18 West, S.B.B.&M., some ten miles upstream from the confluence of Piru Creek and the Santa Clara River. Stream bed elevation at the site is about 1,090 feet, U.S.G.S. datum. The drainage area of Piru Creek above the Upper Blue Point dam site comprises about 370 square miles, and produced an estimated average seasonal runoff during the base period of about 48,700 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 32,800 acre-feet per season during the base period with the present pattern of land use and water supply development.

Consideration was given to the construction of a dam and reservoir at the Upper Blue Point site as one of the several possible alternative locations for terminal storage of water imported from the Sacramento-San Joaquin Delta. This reservoir would regulate such water released from the southern California diversion conduit of the Feather River Project at a point near Quail Lake. The released water would flow through conduits and down natural stream channels, utilizing power drops for the generation of hydroelectric power, en route to Upper Blue Point Reservoir. In the reservoir, the water would be available to meet ultimate supplemental water requirements throughout Ventura County. Consideration was also given to use of Upper Blue Point Reservoir for storage of flood waters of Piru Creek, and utilization of the waters so conserved in the Calleguas-Donejo Hydrologic Unit and in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The Upper Blue Point Reservoir area was mapped in 1951 by Fairchild Aerial Surveys, Incorporated, using photogrammetric methods, for the Ventura County Flood Control District, Zone 2. The resulting map is at a scale of 1 inch equals 400 feet, with a 10-foot contour interval. An enlargement of the reservoir map in the vicinity of the dam site, to a scale of 1 inch equals 100



feet, was used for design of the dam and cost estimating purposes. Data on reservoir areas and capacities for various heights of dam were furnished by the Ventura County Flood Control District, and were based upon the aforementioned map of the reservoir area. Storage capacities of Upper Blue Point Reservoir at various stages of water surface elevation are given in Table 83.

TABLE 83

## AREAS AND CAPACITIES OF UPPER BLUE POINT RESERVOIR

Depth of water at dam, in feet	Water surface elevation U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	1,090	0	0
10	1,100	15	78
20	1,110	23	270
40	1,130	68	1,170
60	1,150	140	3,220
80	1,170	180	6,400
100	1,190	230	10,500
110	1,200	250	12,900
130	1,220	300	18,400
150	1,240	350	24,900
160	1,250	380	28,500
170	1,260	410	32,400
190	1,280	490	41,400
205	1,295	540	50,000
210	1,300	560	51,900
230	1,320	590	63,500
260	1,350	750	83,700
280	1,370	820	99,500
310	1,400	930	125,800

As a result of preliminary geological reconnaissance, it was concluded that an earthfill dam of moderate height is the most feasible at the Upper Blue Point site, and that a high earth or rockfill dam or a masonry dam would be of doubtful feasibility. No geologic work at this site is known, other than the preliminary reconnaissance made in 1952 by geologists of the Division of Water Resources.

The Upper Blue Point site is located at a constriction in the canyon of Piru Creek. The rock includes light brown sandstone, varying from massive to thin bedded, and some shale. Massive sandstones are very prominent on the right abutment, whereas thinner bedded sandstones are prominent on the left abutment, although some massive rock is there also. A few beds of shale appear, particularly

on the left abutment. Concentrations of ferruginous material approaching concretions appear in numerous places in the sandstones.

The left abutment is a fairly narrow nose falling back sharply downstream and somewhat less sharply upstream. The strata on the left abutment are overturned. They strike approximately across the channel and dip very steeply upstream. A similar attitude occurs in the upstream portion of the right abutment. However, south of a fault, which extends down the ravine opposite the approximate center of the left abutment face, the strike is cross-channel, and the strata dip downstream and toward the left abutment at a much gentler angle. The aforementioned fault trends southeasterly from the ravine on the right abutment, crosses the channel section, and probably lies just south of the left abutment face. Farther east, strong evidence of this fault appears in disturbed beds in the walls of the canyon extending eastward south of the left abutment face.

The sandstones on the left abutment are cut by a great number of fracture planes, trending in many directions. The fracture planes have been mostly re-cemented with limonitic material. The sandstones on the right abutment south of the fault appear to have been much less fractured, perhaps because of their massive nature. North of the fault on the right abutment, fracturing of the rocks is similar to that on the left abutment. Open joints are much more numerous on the left abutment, and on the right abutment north of the fault, than on the right abutment south of the fault.

Records of runoff at the Upper Blue Point dam site are not available. However, runoff at the site was estimated as equal to 85 per cent of the measured runoff at the U.S.G.S. stream gaging station on Piru Creek near Piru. The estimates were based on the ratio of respective watershed areas above the dam site and gaging station. The estimated monthly runoff of Piru Creek at the Upper Blue Point site during the base period is presented in Table 84. It may



be noted that runoff at the Blue Point site, about 1,700 feet downstream was assumed to be the same as that at the Upper Blue Point site.

TABLE 84

ESTIMATED MONTHLY RUNOFF OF PIRU CREEK AT UPPER BLUE POINT  
AND BLUE POINT DAM SITES DURING BASE PERIOD

(In acre-feet)

Season	: Oct.	: Nov.	: Dec.	: Jan.	: Feb.	: Mar.	: Apr.	: May	: June	: July	: Aug.	: Sept.	: Total
1936-37	660	160	3,230	2,840	20,010	18,670	9,370	2,830	930	280	120	120	59,220
1937-38	150	210	1,420	990	17,770	70,850	8,610	4,190	2,130	1,160	1,090	880	109,450
1938-39	830	900	9,060	4,120	2,980	6,290	2,910	1,520	590	270	200	2,810	32,480
1939-40	780	700	810	1,780	6,800	2,540	1,790	780	290	90	50	90	16,500
1940-41	320	300	5,190	8,040	47,250	66,910	37,260	15,480	5,670	2,780	1,720	1,440	192,360
1941-42	1,660	1,750	5,700	4,100	2,580	2,620	4,820	2,160	940	450	290	300	27,370
1942-43	410	550	800	26,820	16,370	28,990	6,440	2,970	1,490	810	520	460	86,630
1943-44	640	830	4,820	3,250	23,050	39,170	17,480	9,440	3,820	1,990	1,060	880	106,430
1944-45	1,150	3,530	2,110	2,090	7,820	4,920	3,660	1,840	1,060	370	350	320	29,220
1945-46	780	900	5,920	1,840	2,070	5,100	7,330	1,790	750	440	300	260	27,480
1946-47	470	4,870	9,730	3,180	1,770	1,540	1,220	730	290	130	90	110	24,130
1947-48	160	400	660	570	780	1,190	970	490	220	70	60	70	5,640
1948-49	70	110	630	650	710	1,710	660	280	110	90	60	50	5,130
1949-50	50	120	780	1,160	1,940	900	730	310	50	50	50	50	6,190
1950-51	60	110	130	270	330	440	220	190	120	90	40	50	2,050
Average seasonal runoff, 1936-37 through 1950-51													48,690

It was estimated that a reservoir storage capacity of approximately 50,000 acre-feet would be necessary for terminal storage and regulation of water imported from facilities of the Feather River Project. To determine the safe yield of Upper Blue Point Reservoir with this storage capacity, if used for conservation of Piru Creek flood waters, monthly studies of operation during the base period were made under both the uniform release and rapid release methods of operation. The studies were based on the estimates of runoff of Piru Creek. An allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 12,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 2.20 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies:

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.19	April	0.19
November	0.08	May	0.24
December	0.05	June	0.27
January	0.05	July	0.33
February	0.06	August	0.33
March	0.13	September	<u>0.28</u>
		TOTAL	2.20

The operation studies indicated that under the uniform release method of operation a net safe seasonal yield of 6,500 acre-feet would have been available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, with sufficient reservoir releases to have maintained historical ground water levels in affected basins. Without such releases for maintenance of ground water levels, the net safe yield would have increased to an estimated 9,300 acre-feet per season. Under the rapid release method of operation, a net safe yield of 6,700 acre-feet per season would have been available within the Santa Clara River



Hydrologic Unit. However, under this method of operation only 4,500 acre-feet per season of net safe yield would have been available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits.

Estimates of cost were prepared for a dam at the Upper Blue Point site with a height of 205 feet from stream bed to spillway lip, creating reservoir storage capacity of 50,000 acre-feet. The dam would be a rolled earth-fill structure, comprised of an impervious core of select earth material, and upstream and downstream sections of pervious free-draining material. Both upstream and downstream slopes of the dam would be 3:1, and the impervious section would have slopes of 1:1. The crest width of the dam would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream pervious sections. The upstream face of the dam would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope.

In the cost estimates, it was assumed that depths of about 4 feet of soil plus 4 feet of fractured rock would be stripped beneath the impervious section on the right abutment. Under the impervious section in the channel, a depth of about 60 feet of sand and gravel, including terrace material, would be stripped, and the exposed rock would be shaped. A depth of about 2 feet of soil plus 6 feet of fractured and weathered rock, including alluvial material, would be stripped from the left abutment. A prominent thin rock cliff at the southern end of the left abutment face might have to be removed, at least in part which removal was not included in the cost estimates. Further exploratory work and examination during construction would be required to determine the amount of stripping required on this cliff. Stripping under the pervious sections of the dam was assumed to be a nominal depth of 2 feet of loose surface material and vegetation.

Earth materials considered suitable for the impervious section of the

dam occur in terraces both upstream and downstream from the site. Pervious material is available in the channel and in nearby sandy terraces. An estimated 60 per cent of the material stripped from the right abutment, nearly 100 per cent of that removed from the channel, and about 70 per cent of the material stripped from the left abutment could be used in the pervious section. The nearest source of riprap is a deposit of granite about three miles air line to the northeast of the dam site. It was assumed that compaction of the impervious section of the dam would be effected by either sheepsfoot tampers or pneumatic rollers, and that pneumatic rollers would be used to compact the pervious sections. It was also assumed that moderate grouting would be necessary to prevent minor leakage in the foundation and abutments.

The spillway considered would have a discharge capacity of 100,000 second feet, which is the estimated peak discharge of a once in 1,000-year flood. The spillway was designed as a concrete-lined overpour chute, with an ogee weir control section. The spillway weir and channel would be excavated through the thin left abutment ridge, and would discharge into Piru Creek downstream from the dam. Depth of water above the spillway lip at design discharge capacity would be 20 feet, and an additional 5 feet of residual freeboard would be provided.

It was estimated that the Upper Blue Point Dam would require about two years for construction. A 20-foot diameter concrete lined tunnel of horseshoe section, 1,250 feet in length, was included in the estimate to permit the diversion of Piru Creek waters during the construction period. The tunnel would be constructed through the left abutment of the dam.

After completion of the dam, the diversion tunnel would be used for the outlet from the reservoir. A concrete plug would be placed in the upstream end of the tunnel, and a 72-inch diameter steel pipe would be placed through this plug, extending to a circular reinforced concrete outlet tower located in



the reservoir. Water would enter the tower through four 36-inch diameter inlet valves. The outlet pipe would be supported on ring girders through the tunnel and would terminate in a control house, where a bifurcation structure would be located to permit the discharge of water to either Piru Creek or a proposed conduit. The downstream releases would be controlled by a 48-inch diameter Howell-Bunger valve, and a 48-inch diameter needle valve would control releases to the conduit.

The dam site and a portion of the land in the Upper Blue Point reservoir area are privately owned, while the remainder of the reservoir area belongs to the Federal Government and is a part of the Los Padres National Forest. Cost of acquisition of the private lands was estimated by the Ventura County Flood Control District in 1952 to be about \$33,300. There are no improvements which would have to be acquired or relocated. Field examination of the reservoir area indicated that approximately 640 acres of minor clearing would be required. Prior to construction of the dam, an estimated 1.5 miles of access road would have to be constructed, to replace an existing low standard road.

Presented in Table 85 are pertinent data with respect to general features of the dam and reservoir considered at the Upper Blue Point site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile and section of the dam creating a reservoir with storage capacity of 50,000 acre-feet are shown on Plate 31, entitled "Upper Blue Point Dam on Piru Creek".



TABLE 85

GENERAL FEATURES OF DAM AND RESERVOIR AT  
THE UPPER BLUE POINT SITE ON PIRU CREEK,  
WITH 50,000 ACRE-FOOT STORAGE CAPACITY

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Earthfill Dam

Crest elevation, in feet, U.S.G.S. datum . . . . .	1,320
Crest length, in feet . . . . .	1,110
Crest width, in feet . . . . .	30
Height, spillway lip above stream bed, in feet . . . . .	205
Side slopes, upstream and downstream . . . . .	3:1
Freeboard, above spillway lip, in feet . . . . .	25
Elevation of stream bed, in feet, U.S.G.S. datum . . . . .	1,090
Volume of fill, in cubic yards . . . . .	4,986,000

Reservoir

Surface area at spillway lip, in acres . . . . .	542
Gross storage capacity at spillway lip, in acre-feet . . . . .	50,000
Type of spillway . . . . .	Ogee weir and concrete lined chute
Spillway discharge capacity, in second-feet . . . . .	100,000
Type of outlet . . . . .	Concrete tower, and 72-inch diameter steel pipe through diversion tunnel

---

Presented in Table 86 is a summary of capital and annual costs of a dam and reservoir at the Upper Blue Point site, to create 50,000 acre-feet of storage capacity. Also presented are estimated unit costs of storage capacity and net safe yield of water. The yield referred to is that which would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. Detailed estimates of cost of the dam and reservoir are included in Appendix C.

TABLE 86

SUMMARY OF ESTIMATED COSTS OF DAM, RESERVOIR, AND YIELD OF WATER  
AT THE UPPER BLUE POINT SITE ON PIRU CREEK  
WITH 50,000 ACRE-FOOT STORAGE CAPACITY

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Capital Costs		
Dam and reservoir		\$8,530,000
Cost per acre-foot of storage		170
Cost per acre-foot of net safe yield		1,310
Annual Costs		
Dam and reservoir		438,000
Cost per acre-foot of net safe yield		67

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Blue Point Dam and Reservoir. The Blue Point dam site is located on Piru Creek in Section 10, Township 5 North, Range 18 West, S.B.B. & M., some ten miles upstream from the confluence of Piru Creek and the Santa Clara River, and approximately 1,700 feet downstream from the Upper Blue Point site. Stream bed elevation at the site is about 1,065 feet, U.S.G.S. datum. The drainage area of Piru Creek above the dam site comprises about 371 square miles, and produced an estimated average seasonal runoff during the base period of about 48,700 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 32,800 acre-feet per season during the base period with the present pattern of land use and water supply development.

Consideration was given to the construction of a dam and reservoir at the Blue Point site as one of several possible alternative locations for terminal storage of water imported from the Sacramento-San Joaquin Delta with facilities of the Feather River Project, as described in connection with Upper Blue Point Reservoir in the preceding section. In Blue Point Reservoir, the imported water would be available to meet ultimate supplemental water requirements throughout Ventura County. Consideration was also given to use of Blue Point Reservoir for storage of flood waters of Piru Creek, and utilization of the waters so conserved in the Calleguas-Conejo Hydrologic Unit and in the Oxnard Forebay, Oxnard Plain and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The Blue Point dam site and reservoir area were mapped in 1951 by Fairchild Aerial Survey, Inc., using photogrammetric methods for the Ventura County Flood Control District, Zone 2. The dam site was mapped up to an elevation of 1,700 feet, at a scale of one inch equals 100 feet, with a contour interval of 5 feet. The reservoir area was mapped up to an elevation of 1,250 feet, at a scale of one inch equals 400-feet, with a contour interval of 10 feet. Data on reservoir areas and capacities for various heights of dam were furnished by Ventura County Flood Control District, and were based on the aforementioned map of the reservoir area. Storage capacities of Blue Point Reservoir at various



stages of water surface elevation are given in Table 87.

TABLE 87  
AREAS AND CAPACITIES OF BLUE POINT RESERVOIR

Depth of water at dam, in feet	: Water surface elevation U.S.G.S. datum, in feet	: Water surface area, in acres	: Storage capacity, in acre-feet
0	1,065	0	0
5	1,070	1	3
15	1,080	5	32
25	1,090	11	110
35	1,100	33	330
45	1,110	45	720
65	1,130	98	2,150
85	1,150	170	4,870
105	1,170	220	8,830
125	1,190	270	13,800
135	1,200	300	16,700
155	1,220	350	23,200
175	1,240	410	30,800
185	1,250	440	35,100
195	1,260	480	39,700
210	1,275	540	48,000
215	1,280	560	50,000
235	1,300	640	62,000
255	1,320	730	75,600
285	1,350	850	99,300
305	1,370	920	117,000

Geology of the region at the Blue Point dam site has been studied by Dr. Charles P. Berkey, Paul F. Kerr, Hyde Forbes, and Chester Marliave, and is described in Division of Water Resources Board Bulletin No. 46, published in 1933. The dam site has been explored by trenching on both abutments and by test hole drilling. Five holes were drilled in the stream bed, and four of these penetrated the stream gravels and were continued into bedrock. One hole was bored vertically into the right abutment at an elevation about 160 feet above the stream bed. The following is quoted from Bulletin No. 46 and was taken from a report by Chester Marliave:

"It is believed that on account of foundation conditions, only a flexible type of dam with a broad base should be constructed at this site. No good rock for such type of dam is available in the immediate vicinity but material for an earth fill is found just below the dam site. The earth fill type was therefore selected as the most suitable for this reservoir

- - -

"The region in the vicinity of the dam site is composed entirely of Tertiary sediments which are rather poorly cemented sandstones interbedded with clay shales.

"The regional structure is somewhat complex, the sedimentary beds being considerably folded and in the vicinity of the dam site they are overturned. The intense folding which some of the beds have undergone has resulted in numerous sharp anticlines and synclines which are conspicuous along the canyon in certain places. Accompanying these crustal movements there has been considerable local faulting and slipping, but no major faults were observed in this locality.

- - -

"The bedrock at dam site shows a formational contact. The red beds of the Sespe formation merge into the light colored buff beds of the Vaqueros formation. At the contact there are several hard thin strata of calcareous sandstone about a foot in thickness that are much more resistant than the accompanying strata and act as protective layers preventing disintegration of the softer underlying beds. On account of the inclination of the beds these hard sandstone layers form projecting ridges on each side of the canyon. The softer Vaqueros sediments underlying these harder strata weather easily so that there are high vertical bluffs on their downstream side. Resting upon these hard thin sandstone strata are the red beds of the Sespe formation which are composed of alternating hard and soft layers of sandstone and shale occupying an area 700 feet upstream from the dam site. On either side of the canyon the sedimentary beds dip uniformly upstream at an angle of 50 degrees from the horizontal, while the strike is at right angles to the direction of the stream channel.

"The channel section at the dam site is about 175 feet wide at the constriction of bluffs and somewhat wider along the axis of the dam site. The drill holes put down through the gravels show that bedrock under the stream bed lies close to 90 feet below the surface.- - - The material encountered in these holes where bedrock was reached is the same as that disclosed on the abutments of the dam site.

"There appears to be a minor fault running along the stream bed under the dam site. - - - The straight uniform channel of the stream for a distance of 6,000 feet below the dam site is indicative of a fault, but its continuation upstream is not in evidence although the fault may merge into one of the intense folds.- - -

"The main portion of the left end of the dam should be confined to the small depression upstream from the prominent outcropping rib of harder rock. Two minor faults occur across this abutment within the limits of the dam site. The sediments of the left abutment dip uniformly upstream in a monoclinical structure across the site. There is a large amount of talus material scattered along the bottom of the draw over which the proposed dam would rest. All of this loose material would

have to be removed before any type of dam could be built at this site.

"The right end of the dam should rest in the depression upstream from the prominent outcropped rib of the rock on that side of the canyon. Within the immediate limits of the dam site, the structure at this abutment is monoclinal but the upper portion merges into an inclined syncline which is badly distorted and faulted. One fault traverses the abutment in a vertical direction at an elevation of about 140 feet above the stream bed and has probably crushed the bedrock to a considerable extent. There is a large amount of talus material along the lower slope of this abutment resulting from the weathering of the Sespe formation higher up on the slope of the hill."

Records of runoff at the Blue Point dam site are not available. Runoff at the site was assumed to be the same as at the Upper Blue Point Site, about 1,700 feet upstream. The method of estimating runoff at the Blue Point dam sites is described in the preceding section, and the estimated monthly flow of Piru Creek at the sites during the base period is presented in Table 84.

It was estimated that a reservoir storage capacity of approximately, 50,000 acre-feet would be necessary for terminal storage and regulation of water imported from facilities of the Feather River Project. To determine the safe yield of Blue Point Reservoir with this storage capacity, if used for conservation of Piru Creek flood waters, monthly studies of operation during the base period were made under both the uniform release and rapid release methods of operation. The studies were identical with those described in the previous section for Upper Blue Point Reservoir, and indicated that under the uniform release method of operation a net safe seasonal yield of 6,500 acre-feet would have been available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, with sufficient reservoir releases to have maintained historical ground water levels in affected basins. Without such releases for maintenance of ground water levels, the net safe yield would have increased an estimated 9,300 acre-feet per season. Under the



rapid release method of operation, a net safe yield of 6,700 acre-feet per season would have been available within the Santa Clara River Hydrologic Unit. However, under this method of operation only 4,500 acre-feet per season of net safe yield would have been available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits.

Estimates of cost were prepared for a dam at the Blue Point Site with a height of 215 feet from streambed to spillway lip, creating reservoir storage capacity of 50,000 acre-feet. The dam would be a rolled earthfill structure, comprised of an earth core of select earth material, and upstream and downstream sections of pervious free-draining material. Both upstream and downstream slopes of the dam would be 3:1, and the impervious section would have slopes of 1:1. The crest width of the dam would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream pervious sections. The upstream face of the dam would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope.

In the cost estimates, it was assumed that depths of from 15 to 90 feet of gravel and boulders would be stripped from the stream channel under the impervious section of the dam, and that the exposed rock would be shaped. Under the impervious section on the abutments, depths of from 5 to 30 feet of soil and decomposed rock would be removed. For the pervious sections of the dam, it was assumed that no stripping would be necessary, except for a nominal depth of 2 feet of loose surface material and vegetation.

Earth materials considered suitable for the impervious section of the dam occur in terraces along Piru Creek near the site, and could be obtained from borrow pits located on both sides of the canyon about 1,500 feet downstream from the dam. The outer pervious zones of the dam would consist of stream bed sands and gravels, and materials salvaged from stripping operations. The nearest source of riprap is a deposit of granite about 3.5 miles to the north-

east of the dam site. It was assumed that compaction of the impervious section of the dam would be effected by either sheepsfoot tampers or pneumatic rollers, and that pneumatic rollers would be used to compact the pervious sections. It was also assumed that moderate grouting would be necessary to prevent minor leakage in the foundation and abutments.

The spillway considered would have a discharge capacity of 100,000 second-feet, which is the estimated peak discharge of a once in 1000-year flood. Because of the steep canyon walls on both abutments, any type of spillway placed across them would be extremely costly. For this reason, the spillway for Blue Point Reservoir was designed as a concrete lined tunnel, located through the left abutment. The control structure would consist of a concrete curved ogee weir, 310 feet in length. From the weir, the concrete training walls of the spillway would converge to a width of about 95 feet in a distance of 100 feet. At this point, a second ogee weir would control the flow entering the tunnel. The tunnel would be 1,075 feet in length, and would discharge into a concrete lined channel, 100 feet in length and thence into the channel of Piru Creek several hundred feet downstream from the dam. The spillway was designed to discharge 100,000 second-feet with the tunnel filled to 0.70 depth. With the flow at 0.93 depth, the spillway would discharge 130,000 second-feet, and flowing full it would discharge 120,000 second-feet.

It was estimated that Blue Point Dam would require about two years for construction. Assuming that the spillway tunnel, outlet conduit, impervious excavation, and embankment below the stream bed could be completed in one season, winter flood flows could be passed over the completed embankment without undue harm. The remaining embankment of less than 3,000,000 cubic yards could be placed in the next construction season, thus eliminating the necessity for a large diversion tunnel. It was further assumed that small summer flows could be diverted through the outlet conduit.

The outlet works would consist of a circular reinforced concrete tower located in the reservoir, and a 72-inch diameter steel pipe, 1,450 feet in length, placed in a trench excavated in rock beneath the dam near the right abutment and encased in concrete. Releases from the reservoir would be controlled by four 36-inch diameter gate valves in the outlet tower. The outlet pipe would terminate in a control house downstream from the dam, where a bifurcation structure would be located, permitting the discharge of water to either Piru Creek or a proposed conduit. The downstream releases would be controlled by a 48-inch diameter Howell-Bunger valve, and a 48-inch needle valve would control releases to the conduit.

A portion of the land in the Blue Point reservoir area is privately owned, while the dam site and the remainder of the reservoir area belongs to the Federal Government and is a part of the Los Padres National Forest. Cost of acquisition of the private lands was estimated by the Ventura County Flood Control District in 1952 to be about \$33,300. There are no improvements which would have to be acquired or relocated. Field examination of the reservoir area indicated that approximately 640 acres of minor clearing would be required. Prior to construction of the dam, an estimated 1.2 miles of access road would have to be constructed, to replace an existing low standard road.

Presented in Table 88 are pertinent data with respect to general features of the dam and reservoir considered at the Blue Point Site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section of the dam creating a reservoir with storage capacity of 50,000 acre-feet are shown on Plate 32, entitled "Blue Point Dam on Piru Creek."



TABLE 88

GENERAL FEATURES OF DAM AND RESERVOIR AT THE BLUE POINT SITE ON  
PIRU CREEK, WITH 50,000 ACRE-FOOT STORAGE CAPACITY

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Earthfill Dam		
Crest elevation, in feet, U.S.G.S. datum . . . . .	1,305	
Crest length, in feet . . . . .	830	
Crest width, in feet . . . . .	30	
Height, spillway lip above stream bed, in feet . . . . .	215	
Side slopes, upstream and downstream . . . . .	3:1	
Freeboard, above spillway lip, in feet . . . . .	25	
Elevation of stream bed, in feet, U.S.G.S. datum . . . . .	1,065	
Volume of fill, in cubic yards . . . . .	3,497,700	
Reservoir		
Surface area at spillway lip, in acres . . . . .	536	
Gross storage capacity at spillway lip, in acre-feet . . . . .	50,000	
Type of spillway . . . . .	Tunnel	
Spillway discharge capacity in second-feet . . . . .	100,000	
Type of outlet . . . . .	Concrete tower, and 72-inch diameter steel pipe beneath dam.	

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Presented in Table 89 is a summary of capital and annual costs of a dam and reservoir at the Blue Point Site, to create 50,000 acre-feet of storage capacity. Also presented are estimated unit costs of storage capacity and net safe yield of water. The yield referred to is that which would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. Detailed estimates of cost of the dam and reservoir are included in Appendix C.

TABLE 89

SUMMARY OF ESTIMATED COSTS OF DAM, RESERVOIR, AND YIELD  
OF WATER AT THE BLUE POINT SITE ON PIRU CREEK,  
WITH 50,000 ACRE-FOOT STORAGE CAPACITY

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Capital Costs	
Dam and reservoir . . . . .	\$8,171,000
Cost per acre-foot of storage. . . . .	160
Cost per acre-foot of net safe yield . . . . .	1,260
Annual Costs	
Dam and reservoir . . . . .	420,000
Cost per acre-foot of net safe yield . . . . .	65

---

Devil Canyon Dam and Reservoir. The Devil Canyon dam site is located on Piru Creek in Section 22, Township 5 North, Range 18 West, S.B.B. & M., some eight miles upstream from the confluence of Piru Creek and the Santa Clara River. Stream bed elevation at the site is about 980 feet, U.S.G.S. datum. The drainage area of Piru Creek above the Devil Canyon dam site comprises about 392 square miles, and produced an estimated average seasonal runoff during the base period of about 51,500 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 34,700 acre-feet per season during the base period with the present pattern of land use and water supply development.

Consideration was given to the construction of a dam and reservoir at the Devil Canyon site as one of several possible alternative locations for terminal storage of water imported from the Sacramento-San Joaquin Delta with facilities of the Feather River Project, as was described in connection with Upper Blue Point Reservoir in a prior section. In Devil Canyon Reservoir, the imported water would be available to meet ultimate supplemental water requirements throughout Ventura County. Consideration was also given to use of Devil Canyon Reservoir for storage of flood waters of Piru Creek, and utilization of the waters so conserved in the Calleguas-Conejo Hydrologic Unit and in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit. Devil Canyon Reservoir, if constructed with sufficient storage capacity, could be used for joint regulation of imported water and conservation of local flood flows.

The Devil Canyon dam site and reservoir area were surveyed in 1951 by Fairchild Aerial Surveys, Inc., using aerial photogrammetric methods, for the Ventura County Flood Control District, Zone 2. The dam site was mapped up to an elevation of 1,450 feet, at a scale of one inch equals 100 feet, with a 5-foot contour interval. The reservoir area was mapped up to an elevation of 1,350 feet, at a scale of one inch equals 400 feet, with a contour interval at 10 feet. Data



on storage capacities of Devil Canyon Reservoir at various stages of water surface elevation, based on the aforementioned map, were obtained from the Ventura County Flood Control District and are presented in Table 90.

TABLE 90

## AREAS AND CAPACITIES OF DEVIL CANYON RESERVOIR

Depth of water at dam, in feet	:	Water surface	:	:
	:	elevation	:	Storage capacity,
	:	U.S.G.S. datum,	:	in acre-feet
	:	in feet	:	:
0		980		0
10		990		40
20		1,000		18
30		1,010		515
40		1,020		1,060
50		1,030		1,820
60		1,040		2,800
70		1,050		4,090
80		1,060		5,870
90		1,070		8,200
100		1,080		10,900
110		1,090		14,000
120		1,100		17,500
130		1,110		21,500
140		1,120		25,900
150		1,130		30,900
160		1,140		36,500
170		1,150		42,700
180		1,160		49,300
190		1,170		56,500
200		1,180		64,200
210		1,190		72,400
220		1,200		81,200
230		1,210		90,500
240		1,220		100,000
250		1,230		110,900
260		1,240		122,100
270		1,250		133,900
280		1,260		146,300
285		1,265		153,000
290		1,270		159,400
300		1,280		173,300
310		1,290		187,900
320		1,300		203,300
330		1,310		220,600
340		1,320		236,700
350		1,330		254,600
360		1,340		273,400
370		1,350		292,900

Based on preliminary geological reconnaissance, the Devil Canyon dam site is considered best adapted to a rolled fill type of dam of moderate height. A geologic investigation of the site was made in 1951 as a part of the current investigation. The geology of the region and dam site was previously investigated for and is described in Division of Water Resources Bulletin No. 46. The recent geologic examination considered greater heights of dam than were contemplated in Bulletin No. 46. Foundation exploration prior to 1933 included the drilling of five drill holes and the sinking of two test pits. Further exploration by the United Water Conservation District in 1952 included four drill holes.

The abutments and foundation at the Devil Canyon dam site lie in an area occupied by the Modelo formation, here exemplified by a series of thin interbedded sandstones and shales. They are not well cemented or indurated, although leaching of soluble salts to the surface has hardened some of the beds. Where naturally exposed, some of the beds are strongly weathered, but road cuts made 20 years ago in the thin shaly beds show the material to be in generally good condition. The steep slopes have a relatively thin soil cover, and support only a slight growth of grass and brush. The bedding is markedly evident, particularly on the left abutment. There is some evidence of openness along some of the joints and bedding planes of the Modelo formation near the surface, part of which may be due to solution.

Structurally, the dam site lies on the southerly limb of an east-west trending anticline, with the bed striking across the channel and dipping from 40 to 50 degrees downstream. The structure appears continuous, and no break is discernible in the channel section. The drill holes and test pits reported in Bulletin No. 46 showed the maximum depth of fill in the stream bed to be from 80 to 90 feet. The holes drilled in 1952 indicated that the depth of channel fill varied from 36 to 67 feet.



A small fault crosses the right abutment several hundred feet downstream from the axis of the dam, but it is not considered active and should present no insoluble problem. Although a large earthen dam would overlap this fault, only the downstream toe would reach it, and it is believed that only moderate additional excavation would be required. A few small seeps were noted near the base of the right abutment at the elevation of the road.

Records of runoff at the Devil Canyon dam site are not available. However, runoff at the site was estimated as equal to 90 per cent of the measured runoff at the U.S.G.S. stream gaging station on Piru Creek near Piru. The estimates were based on the ratio of respective watershed areas above the dam site and gaging station. The estimated monthly runoff of Piru Creek at the Devil Canyon dam site during the base period is presented in Table 91.

TABLE 91

## ESTIMATED MONTHLY RUNOFF OF PIRU CREEK AT DEVIL CANYON DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	Oct. :	Nov. :	Dec. :	Jan. :	Feb. :	Mar. :	Apr. :	May :	June :	July :	Aug. :	Sept. :	Total
1936-37	700	170	3,420	3,010	21,190	19,770	9,920	3,000	980	290	130	130	62,710
1937-38	150	220	1,500	1,040	18,820	75,000	9,120	4,440	2,250	1,220	1,150	930	115,840
1938-39	880	950	9,590	4,370	3,150	6,660	3,080	1,610	620	290	210	2,970	34,380
1939-40	830	740	860	1,880	7,200	2,690	1,900	820	310	90	50	100	17,470
1940-41	340	320	5,490	8,510	50,030	70,850	39,460	16,390	6,000	2,940	1,820	1,520	203,670
1941-42	1,750	1,850	6,040	4,340	2,730	2,770	5,100	2,290	990	480	310	320	28,970
1942-43	430	580	850	28,400	17,330	30,690	6,820	3,140	1,570	860	550	490	91,710
1943-44	680	880	5,100	3,440	24,410	41,470	18,500	10,000	4,040	2,100	1,120	940	112,680
1944-45	1,210	3,740	2,230	2,210	8,280	5,210	3,880	1,950	1,130	390	370	340	30,940
1945-46	820	950	6,270	1,940	2,200	5,400	7,760	1,890	790	470	320	280	29,090
1946-47	490	5,160	10,300	3,370	1,870	1,630	1,300	770	310	140	90	110	25,540
1947-48	170	420	700	600	830	1,260	1,030	520	230	80	60	70	5,970
1948-49	70	120	670	690	750	1,810	700	300	120	100	60	50	5,440
1949-50	50	130	830	1,230	2,060	950	770	330	50	50	50	50	6,550
1950-51	60	120	140	280	350	470	230	200	130	100	40	50	2,170
Average seasonal runoff, 1936-37 through 1950-51													51,540

Based on the estimates of runoff, monthly studies of operation of Devil Canyon Reservoir during the base period were made for reservoir storage capacities of 100,000 acre-feet and 150,000 acre-feet, respectively, under both the uniform release and rapid release methods of operation, with utilization of the conserved water in the Santa Clara River Hydrologic Unit. Similar operation studies also were made for a Devil Canyon Reservoir of 150,000 acre-feet storage capacity, with utilization of the conserved water in both the Santa Clara River and Calleguas-Conejo Hydrologic Units. In these latter studies, the lower 100,000 acre-feet of reservoir storage was allocated to the Santa Clara River Hydrologic Unit, with operation under the uniform release criteria. The upper 50,000 acre-feet of reservoir storage was allocated jointly to both hydrologic units, with releases for the Santa Clara River Hydrologic Unit being under the uniform release criteria, and with releases for the Calleguas-Conejo Hydrologic Unit being as rapid as permitted by the capacity of the conduit to serve the Unit hereinafter referred to as the "Piru-Las Posas Conduit". Seven sizes of conduit were considered, varying in discharge capacity from 40 to 200 second-feet.

In all yield studies, an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 13,000 acre-feet. This amount represents the estimated loss after 20 years of operation. An average net seasonal depth of evaporation from the reservoir water surface of 2.20 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies:

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.19	April	0.19
November	0.08	May	0.24
December	0.05	June	0.27
January	0.05	July	0.33
February	0.06	August	0.33
March	0.13	September	<u>0.28</u>
		TOTAL	2.20



The estimated values of net safe seasonal yield that would be obtained from Devil Canyon Reservoir under both the uniform release and rapid release operating criteria, with utilization of the conserved water in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit, are presented in Table 92. The relationship between reservoir storage capacity and net safe seasonal yield, with Devil Canyon Reservoir operated by the uniform release method with releases for maintenance of historic ground water levels is depicted graphically on Plate 36.

TABLE 92  
 ESTIMATED NET SAFE SEASONAL YIELDS OF DEVIL CANYON  
 RESERVOIR IF OPERATED SOLELY FOR BENEFIT OF SANTA CLARA  
 RIVER HYDROLOGIC UNIT

(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	Available to Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, with releases for maintenance of ground water levels	Available to Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, without releases for maintenance of ground water levels	Available within Santa Clara River Hydrologic Unit	Available to Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits
100,000	15,000	19,000	15,500	10,500
150,000	22,000	27,000	22,700	15,000

The estimated seasonal amounts of water that could have been diverted to the Calleguas-Conejo Hydrologic Unit during the base period, with a Devil Canyon Reservoir of 150,000 acre-foot storage capacity operated for joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units, are presented in Table 93. The estimates include seasonal diversions with seven alternative sizes of Piru-Las Posas Conduit, and contemplated releases of water for the Santa Clara River Hydrologic Unit under the uniform release operating criteria, including the amounts necessary to maintain historic ground water levels in affected basins. Table 94 presents corresponding estimates of net safe seasonal yield that would be available to each of the hydrologic units with a Devil Canyon Reservoir of

150,000 acre-foot storage capacity operated as described. It should be noted that the yields shown in Table 94 could be increased substantially if reservoir releases were not required for maintenance of historic ground water levels.

TABLE 93

ESTIMATED SEASONAL POTENTIAL FOR DIVERSION OF WATER  
FROM DEVIL CANYON RESERVOIR TO CALLEGUAS-CONEJO HYDROLOGIC UNIT  
DURING BASE PERIOD, WITH OPERATION OF  
150,000 ACRE-FOOT RESERVOIR FOR JOINT BENEFIT  
OF SANTA CLARA RIVER AND CALLEGUAS-CONEJO HYDROLOGIC UNITS

(In acre-feet)

Season	Discharge capacity of Piru-Las Posas Conduit, in second feet						
	40	60	80	100	125	150	200
1936-37	0	0	0	0	0	0	0
1937-38	16,980	23,470	33,960	42,450	47,460	49,710	51,780
1938-39	28,960	34,700	32,040	23,630	18,710	16,530	14,550
1939-40	15,730	3,320	0	0	0	0	0
1940-41	19,200	28,800	38,400	48,000	60,000	72,000	96,000
1941-42	28,960	39,870	42,980	40,280	34,270	28,260	16,250
1942-43	28,960	32,490	43,320	54,150	60,250	63,080	65,560
1943-44	28,960	43,440	57,920	55,780	61,730	72,000	83,800
1944-45	28,960	39,870	41,100	38,570	32,190	24,670	14,700
1945-46	23,940	12,850	6,930	5,380	5,380	5,380	5,370
1946-47	9,020	4,670	4,670	3,980	3,980	3,980	3,980
1947-48	0	0	0	0	0	0	0
1948-49	0	0	0	0	0	0	0
1949-50	0	0	0	0	0	0	0
1950-51	0	0	0	0	0	0	0
Averages	15,310	17,570	20,090	20,820	21,600	22,370	23,470

TABLE 94

ESTIMATED NET SAFE SEASONAL YIELDS OF 150,000 ACRE-FOOT  
DEVIL CANYON RESERVOIR, IF OPERATED FOR JOINT BENEFIT OF  
SANTA CLARA RIVER AND CALLEGUAS-CONEJO HYDROLOGIC UNITS

Discharge capacity of Piru-Las Posas Conduit, in second- feet	: Available net safe yield, with reservoir releases : for maintenance of historic ground water levels, : in acre-feet per season		
	To Santa Clara	:	:
	River Hydrologic	:	To Calleguas-
	Unit, under uni-	:	Conejo Hydrologic
	form release	:	Unit
	criteria	:	:
			Totals
40	13,500	15,300	28,800
60	13,300	17,600	30,900
80	13,300	20,100	33,400
100	13,300	20,800	34,100
125	13,300	21,600	34,900
150	13,300	22,400	35,700
200	13,300	23,500	36,800

As a result of the geologic investigation and the reservoir yield studies, estimates of cost were prepared for dams at the Devil Canyon site with heights of 240 feet and 285 feet from stream bed to spillway lip, creating reservoir storage capacities of 100,000 acre-feet and 150,000 acre-feet, respectively. For both heights of dam, a rolled fill structure was contemplated, comprising an impervious core of select earth material, and upstream and downstream sections of pervious free-draining material. Both upstream and downstream slopes of the dam would be 3:1 for the dam of 240-foot height, and 3.25:1 for the dam of 285-foot height. The impervious section would have slopes of 1:1. Crest widths would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream pervious sections. The upstream face of the dams would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope.



In the cost estimates, it was assumed that a depth of about 75 feet of sand, gravel, and boulders would be stripped under the impervious core in the channel. On the right abutment, depths of about 5 feet of soil plus 5 feet of weathered fractured sandstone and shale would be stripped. On the left abutment, it was assumed that depths of about 2 feet of soil and 4 feet of fractured rock would be stripped. For the pervious sections of the dam, a nominal depth of stripping of 2 feet was assumed.

Sufficient materials for construction of Devil Canyon Dam are available within two miles or less of the site. Borrow pit drilling by the United Water Conservation District in 1952 revealed the presence of about 3,850,000 cubic yards of impervious fill material. Three samples of material taken from the possible borrow areas were tested by the Division of Water Resources and were deemed adequate for use in the impervious section. Suitable pervious material from the stream bed exists in unlimited quantities. Material salvaged from the stripping excavation would be suitable for this purpose. Granitic rock for riprap is available at a location about five miles upstream from the dam site. It was assumed that compaction of the impervious section of the dam would be effected by either sheepsfoot tampers or pneumatic rollers, and that pneumatic rollers would be used to compact the pervious section.

Spillways, for both heights of dam considered, would have a discharge capacity of 102,000 second-feet, which is the estimated peak discharge of a once in 1,000-year flood. Spillways for both heights of dam would be excavated through the right abutment, would be of the chute type, and would be concrete lined throughout. For the lower dam, topographical considerations required that the spillway entrance be of the side channel type. For the higher dam, topographical considerations permitted use of the conventional ogee weir at the spillway entrance. Depth of water above the spillway lip would be 20 feet, and an additional 5 feet of residual freeboard would be provided.

It was estimated that the dam of 240-foot height could be constructed in two years, while the dam of 285-foot height would require three years for construction. Diversion of winter flood flows in Piru Creek would be effected through a 21-foot diameter concrete lined tunnel of horseshoe section constructed through the left abutment. The tunnel would be about 1,750 feet in length for the lower dam, and about 2,130 feet in length for the higher dam.

It was assumed that for either size of dam, the outlet conduit would pass through the diversion tunnel. For this purpose, the tunnel would be plugged at its upstream end, with the concrete plug encasing the outlet conduit. The approach channel for the outlet works would be 160 feet in length, with a varying bottom width and 1:1 side slopes. Maximum depth of the cut would be about 30 feet. For the lower dam, a submerged concrete intake structure would be located immediately upstream from the tunnel portal. This structure would consist of a concrete chamber, where in would be located hydraulic and manual controls for a high pressure slide gate which would regulate discharge through the outlet pipe. The intake for the outlet pipe would be located about 25 feet above the floor of the tunnel. The outlet conduit would consist of a 72-inch diameter steel pipe, and would be supported by ring girders resting on the floor of the tunnel. The conduit would terminate at a control house located at the downstream portal of the tunnel, wherein releases would be further regulated by a 60-inch diameter needle valve. Access to the pipe and intake structure would be maintained through the diversion tunnel.

For the higher dam, the intake structure would be a reinforced concrete tower in the reservoir, wherein would be located five 36-inch diameter inlet valves. The outlet conduit would be similar to the one for the lower dam, except that the pipe would terminate in a bifurcation structure in the control house. A 48-inch diameter needle valve would regulate releases of water into a pipe line, and a 48-inch diameter Howell-Bunger valve would regulate releases into the stream bed.

From field examination of the Devil Canyon Reservoir area, it was estimated that, depending upon height of dam to be constructed, from 1,050 to 1,500 acres of minor clearing would be required. The dam and reservoir area is owned by the Federal Government and is a part of the Los Padres National Forest, except for six privately owned parcels with minor improvements. The privately owned lands were appraised by the Ventura County Flood Control District in 1952, and their cost of acquisition was estimated to be \$110,250. In the estimate, no valuation was placed upon mineral rights and oil leases.

Presented in Table 95 are pertinent data with respect to the general features of the two sizes of dams and reservoirs considered at the Devil Canyon site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 150,000 acre-feet are shown on Plate 33, entitled "Devil Canyon Dam on Piru Creek".



TABLE 95

GENERAL FEATURES OF TWO SIZES OF DAM AND RESERVOIR  
AT THE DEVIL CANYON SITE ON  
PIRU CREEK

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Earthfill Dam

Crest elevation, in feet, U.S.G.S. datum . . . . .	1,245	1,290
Crest length, in feet . . . . .	1,050	1,180
Crest width, in feet . . . . .	30	30
Height, spillway lip above stream bed, in feet . . . . .	240	285
Side slopes, upstream and downstream . . . . .	3:1	3.25:1
Freeboard, above spillway lip, in feet . . . . .	25	25
Elevation of stream bed, in feet, U.S.G.S. datum . . . . .	980	980
Volume of fill, in cubic yards . . . . .	6,363,500	9,888,900

Reservoir

Surface area at spillway lip, in acres . . . . .	1,021	1,315
Gross storage capacity at spillway lip, in acre-feet . . . . .	100,000	150,000
Type of spillway . . . . .	Side channel and concrete lined chute	Ogee weir and concrete lined chute
Spillway discharge capacity, in second-feet . . . . .	102,000	102,000
Type of outlet . . . . .	72-inch diameter steel pipe through diversion tunnel	Concrete tower, and 72-inch diameter steel pipe through diversion tunnel

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Presented in Table 96 is a summary comparison of capital and annual costs of the two considered sizes of dam and reservoir at the Devil Canyon site. Also presented in Table 96 are estimated unit costs of storage capacity and net safe yields of water that would be developed by construction of the two sizes of reservoir, with reservoir operation for the sole benefit of the Santa Clara River Hydrologic Unit under the uniform release operating criteria with release for maintenance of historic ground water levels. Certain of the relationships presented in Table 96 are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the two sizes of dam and reservoir at the Devil Canyon site are included in Appendix C.

TABLE 96

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF WATER  
AT THE DEVIL CANYON SITE ON PIRU CREEK,  
WITH RESERVOIR OPERATION SOLELY FOR BENEFIT  
OF SANTA CLARA RIVER HYDROLOGIC UNIT

Item	Reservoir storage capacity,	
	in acre-feet	
	100,000	150,000
Capital Costs		
Dam and reservoir	\$12,120,000	\$15,490,000
Cost per acre-foot of storage	121	103
Cost per acre-foot of net safe yield	810	700
Annual Costs		
Dam and reservoir	625,000	798,000
Cost per acre-foot of net safe yield	42	36
Cost per acre-foot of incremental net safe yield	--	25

Estimates of annual unit costs of net safe yields of water from a Devil Canyon Reservoir of 150,000 acre-foot storage capacity, with seven alternative sizes of Piru-Las Posas conduit, operated for the joint benefit of both the Santa Clara River and Calleguas-Conejo Hydrologic Units, are presented in Table 97. The estimates were based on the previously described

criteria of reservoir operation, including releases of water for the Santa Clara River Hydrologic Unit by the uniform release method, and releases for maintenance of historic ground water levels in affected basins.

TABLE 97

ESTIMATED UNIT COSTS OF YIELDS OF WATER  
FROM 150,000 ACRE-FOOT DEVIL CANYON RESERVOIR,  
WITH RESERVOIR OPERATION FOR JOINT BENEFIT OF SANTA CLARA RIVER  
AND CALLEGUAS-CONEJO HYDROLOGIC UNITS

Discharge capacity of Piru-Las Posas Conduit, in second-feet	:	Annual costs per acre-foot : of net safe yield at reservoir
40		\$28
60		26
80		24
100		23
125		23
150		22
200		22



Santa Felicia Dam and Reservoir. The Santa Felicia dam site is located on Piru Creek in the Rancho Temescal land grant, some five miles upstream from the confluence of Piru Creek and the Santa Clara River. Stream bed elevation at the site is about 870 feet, U.S.G.S. datum. The drainage area of Piru Creek above the Santa Felicia dam site comprises about 422 square miles, and produced an estimated average seasonal runoff during the base period of about 55,800 acre-feet. It was estimated that waste to the ocean of water originating above the dam site would have averaged about 37,600 acre-feet per season during the base period with the present pattern of land use and water supply development. Consideration was given to the construction of a dam and reservoir at the Santa Felicia site for storage of flood waters in Piru Creek, and utilization of the waters so conserved in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

The Santa Felicia dam site and reservoir area were surveyed in 1951 by Fairchild Aerial Surveys, Inc., using photogrammetric methods, for the Ventura County Flood Control District, Zone 2. The dam site was mapped up to an elevation of 1,300 feet, at a scale of one inch equals 100 feet, with a 5-foot contour interval. The reservoir area was mapped up to an elevation of 1,250 feet, at a scale of one-inch equals 400 feet, with a contour interval of 10 feet. Storage capacities of Santa Felicia Reservoir at various stages of water surface elevation, derived from the foregoing reservoir area map, are given in Table 98.

TABLE 98  
AREAS AND CAPACITIES OF SANTA FELICIA RESERVOIR

: Water surface : : Depth of water : elevation : Water surface : Storage capacity, at dam, in feet : U.S.G.S. datum, : area, in acres : in acre-feet : in feet : :			
0	870	0	0
10	880	11	60
20	890	47	350
30	900	65	860
40	910	110	1,730
50	920	150	3,050
60	930	210	4,870
70	940	270	7,270
80	950	390	10,600
90	960	500	15,100
100	970	580	20,400
110	980	690	26,800
120	990	750	34,000
130	1,000	810	41,800
140	1,010	880	50,300
150	1,020	960	59,500
160	1,030	1,030	69,400
165	1,035	1,070	74,600
170	1,040	1,100	80,100
180	1,050	1,190	91,500
187	1,057	1,280	100,000
190	1,060	1,320	104,000
200	1,070	1,420	117,800
210	1,080	1,510	132,100
220	1,090	1,600	148,000
230	1,100	1,710	164,500
240	1,110	1,810	182,100
250	1,120	1,940	200,900
260	1,130	2,070	220,900
270	1,140	2,210	242,300
280	1,150	2,330	265,000
290	1,160	2,460	289,000
300	1,170	2,590	314,300
310	1,180	2,730	340,900
320	1,190	2,870	368,900
330	1,200	3,010	398,300
340	1,210	3,160	429,200
350	1,220	3,300	461,500
360	1,230	3,460	495,300
370	1,240	3,620	530,700
380	1,250	3,730	567,400

Based upon preliminary geological reconnaissance, the Santa Felicia dam site appears to be suitable for a moderately high earthen dam. Dr. Charles P. Berkey reported on the geology of the Santa Felicia dam site in 1947. A program of foundation and borrow area exploration at this site, including soil testing, was conducted by the United Water Conservation District in 1952, under the direction of M.F. Thiel. Except as noted, the geology hereinafter described is based upon preliminary geological reconnaissance conducted by the Division of Water Resources in 1951.

The axis of the proposed Santa Felicia Dam is located on the southwesterly or downstream limb of an anticline in Modelo sandstones, siltstone, and shales of Miocene age. The strike is across the canyon, more or less east to west, and dip at the axis of the dam is about 40 to 50 degrees downstream. Several of the sandstone members, being more resistant to erosion, stand out prominently and help to create a slight constriction in an otherwise uniformly wide valley. The sandstone and shales are well bedded, and generally the shale beds are much thinner and more broken. Acid tests reveal very little calcareous cement in the sandstones at the dam axis. The anticlinal structure is very pronounced. The northward dipping limb is about 0.25 mile upstream from the dam site, with a crushed zone near the axis of the fold where it apparently snapped. A large number of producing oil wells have been drilled on this structure in the vicinity of the dam site. Beds are moderately well jointed but should not be expected to leak excessively.

The nose of the ridge forming the right abutment is not very thick. Both abutments are relatively steep, with slopes on the order of 1.5:1, though not entirely uniform. However, above about 200 feet from stream bed the right abutment flattens out thus providing a good location for the spillway. Terrace deposits of silty, clayey, and gravelly sands, on the order of 40 feet deep, are found on the ridge in the proposed spillway area, both up and down stream from the axis of the dam. However, one hole drilled in this area by United Water Conservation District indicated a depth of terrace material of about 66 feet.



Under the program of foundation and borrow area exploration conducted by United Water Conservation District in 1952, 36 holes were drilled, amounting to about 2,000 lineal feet of overburden drilling and about 1,300 lineal feet of rock core drilling. Overburden in the stream bed was found to be composed of a mixture of sand, gravel, cobbles, and boulders, while on the abutments and spillway site it was composed of gravel, sand, silt, and clay. Overburden in the stream bed was a maximum of 85 feet in depth, and in the spillway area the depth of overburden varied from 0 to 66 feet. Rock cores taken showed the dam site to be underlain by thick beds of moderately soft massive sandstone and thick beds of soft to hard shale. Water pressure testing of most of the holes drilled in the stream bed indicated that little or no grouting in the bedrock would be required, and led to the assumption that the bedrock will be practically water tight. It was further assumed that in all probability the reservoir will also be water tight, due to the tightness of the bedrock and the general impervious nature of the soil overlying the bedrock except in the stream bed.

Records of runoff at the Santa Felicia dam site are not available. However, runoff at the site was estimated as equal to 97.5 per cent of the measured runoff at the U.S.G.S. stream gaging station on Piru Creek near Piru. The estimates were based on the ratio of respective watershed areas above the dam site and gaging station. The estimated monthly runoff of Piru Creek at the Santa Felicia dam site during the base period is presented in Table 99.

TABLE 99

## ESTIMATED MONTHLY RUNOFF OF PIRU CREEK AT SANTA FELICIA DAM SITE DURING BASE PERIOD

(In acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1936-37	760	180	3,710	3,260	22,950	21,420	10,740	3,250	1,060	320	140	140	67,930
1937-38	170	240	1,630	1,130	20,390	81,260	9,880	4,800	2,440	1,320	1,250	1,000	125,510
1938-39	950	1,030	10,390	4,730	3,410	7,220	3,330	1,750	670	310	230	3,220	37,240
1939-40	900	800	930	2,040	7,800	2,910	2,060	890	340	100	60	100	18,930
1940-41	370	350	5,950	9,220	54,200	76,750	42,740	17,750	6,500	3,190	1,970	1,650	220,640
1941-42	1,900	2,010	6,540	4,700	2,950	3,000	5,530	2,480	1,070	520	340	340	31,380
1942-43	470	630	920	30,760	18,780	33,250	7,390	3,400	1,700	930	600	530	99,360
1943-44	730	950	5,530	3,720	26,440	44,930	20,050	10,830	4,380	2,280	1,220	1,010	122,070
1944-45	1,320	4,050	2,420	2,400	8,970	5,640	4,200	2,120	1,220	420	400	370	33,530
1945-46	890	1,030	6,800	2,110	2,380	5,850	8,400	2,050	860	510	340	300	31,520
1946-47	540	5,590	11,160	3,650	2,030	1,760	1,400	830	340	150	100	120	27,670
1947-48	180	460	750	650	900	1,360	1,110	570	250	80	70	80	6,460
1948-49	80	130	720	740	810	1,960	750	320	130	100	70	50	5,860
1949-50	60	130	890	1,330	2,220	1,030	830	320	60	60	60	60	7,050
1950-51	70	130	150	310	380	500	250	230	130	100	40	50	2,340
Average seasonal runoff, 1936-37 through 1950-51													55,830

Based on the estimates of runoff, monthly studies of operation during the base period were made for storage capacities of 50,000 acre-feet, 75,000 acre-feet, and 100,000 acre-feet at the Santa Felicia site, under both the uniform release and rapid release methods of operation. In all of the studies an allowance was made for reduction in effective reservoir storage capacity due to sedimentation, in the amount of 14,000 acre-feet. This amount represents the estimated loss after about 20 years of operation. An estimated average net seasonal depth of evaporation from the reservoir water surface of 2.20 feet, distributed monthly in accordance with the following tabulation, was employed in the operation studies.

<u>Month</u>	<u>Net evaporation, in feet of depth</u>	<u>Month</u>	<u>Net evaporation, in feet of depth</u>
October	0.19	April	0.19
November	0.08	May	0.24
December	0.05	June	0.27
January	0.05	July	0.33
February	0.06	August	0.33
March	0.13	September	<u>0.28</u>
		TOTAL	2.20

The estimated values of net safe seasonal yield that would be obtained under both the uniform release and rapid release operating criteria are presented in Table 100. The relationship between reservoir storage capacity and net safe seasonal yield, with Santa Felicia Reservoir operated by the uniform release method, and with releases for maintenance of ground water levels in affected basins, is depicted graphically on Plate 36.



TABLE 100  
ESTIMATED NET SAFE SEASONAL YIELDS OF SANTA FELICIA RESERVOIR  
(In acre-feet)

Reservoir storage capacity	Uniform release operation		Rapid release operation	
	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : with releases for : maintenance of ground : water levels :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits, : without releases : for maintenance of : ground water levels :	Available within : Santa Clara River : Hydrologic Unit :	Available to Oxnard : Forebay, Oxnard : Plain, and Pleasant : Valley Subunits :
50,000	6,600	9,500	6,800	4,600
75,000	11,000	14,300	11,300	7,500
100,000	15,000	19,000	15,500	10,500

As a result of the geologic investigation and the reservoir yield studies, estimates of cost were prepared for dams at the Santa Felicia site with heights of 140 feet, 165 feet, and 187 feet from stream bed to spillway lip, creating reservoir storage capacities of 50,000 acre-feet, 75,000 acre-feet and 100,000 acre-feet, respectively. A dam with height of 187 feet is the highest that could be constructed without flooding the Blue Point site. Furthermore, with higher dams it would not be possible to utilize the ridge which forms the right abutment for a spillway location, and spillway costs would be proportionately greater.

For all heights of dam considered, a rolled fill structure was contemplated, comprising an impervious core of select earth material, and upstream and downstream sections of pervious free draining sands and gravels. Both upstream and downstream slopes of the dam would be 2.5:1 for the dam of 140-foot height, and 3:1 for the two higher dams. The impervious section would have slopes of 1:1. Crest widths would be 30 feet, comprised of a 10-foot width for the impervious core, and 10-foot widths each for the upstream and downstream pervious sections. The upstream face of the dam would be protected against wave action by rock riprap placed to a depth of 3 feet normal to the slope.

In the cost estimates, it was assumed that depths of about 4 feet of soil and 6 feet of fractured and weathered sandstone and shale would be stripped from the right abutment under the impervious section. In the stream channel, about 600 feet in width, an estimated depth of 75 feet of sands, gravels, and cobbles would have to be removed under the impervious section. Most of this stripping would be below the water table, and would require dewatering during excavation and backfill. Under the impervious section on the left abutment, estimated depths of about 3 feet of soil and 6 feet of fractured and weathered rock would be stripped. For the pervious sections of the dam, a nominal depth of stripping of from 2 to 4 feet was assumed.

The borrow pit drilling by the United Water Conservation District in 1952 revealed the presence of about 3,850,000 cubic yards of impervious fill material within about 1.3 miles of the dam site. Soil tests showed that these borrow soils, when compacted, are impervious, well-graded mixtures of gravel, sand, and silt or clay. In addition, a portion of the material stripped from both abutments could be salvaged for impervious fill. Pervious material from the stream bed exists in unlimited quantities, and all of the material stripped from the channel section could be salvaged for the pervious fill. The nearest source of granite for riprap is some five miles distant, or stream bed gravels, cobbles, and boulders could be used for riprap purposes. It was assumed that compaction of the impervious fill of the dam would be effected by either sheepsfoot tampers or pneumatic rollers, and that pneumatic rollers would be used to compact the pervious sections. The estimates included provision for light grouting of the foundation, increasing with the height of dam.

Spillways, for all heights of dam considered, would have a discharge capacity of 103,000 second-feet, which is the estimated peak discharge of a once in 1,000-year flood. The spillways were designed as concrete-lined chutes, with ogee weir control sections. They would be constructed across the ridge forming the right abutment of the dam, and would discharge into Piru Creek



below the dam. Depth of water above the spillway lip at design discharge capacity would be 15 feet, and an additional 5 feet of residual freeboard would be provided.

As it was estimated that the dam of 140-foot height could be constructed in one year, it was assumed that diversion of summer flow in Piru Creek would be effected through the outlet conduit. For the two higher dams, requiring an estimated two years of construction, a 22-foot diameter concrete lined tunnel of horseshoe section was included in the estimates, to provide for diversion of winter flows. The tunnel would be about 1,080 feet in length for the dam of 165-foot height, and about 1,270 feet in length for the dam of 187-foot height.

It was assumed that outlet works for both of the larger dams considered would utilize the diversion tunnel after constructed. The approach channel for the outlet works would be 100 feet in length, with a varying bottom width and 1:1 side slopes. Maximum depth of cut would be about 50 feet. The first 60 feet of tunnel would be plugged with concrete, encasing the outlet pipe. A submerged concrete intake structure would be located immediately upstream from the tunnel portal. This structure would consist of a chamber, wherein would be located hydraulic and manual controls for a high pressure slide gate, which would regulate discharge through the outlet pipe. The intake for the outlet conduit would be located about 25 feet above the floor of the tunnel. The outlet conduit would consist of a 72-inch diameter steel pipe, supported by ring girders resting on the floor of the tunnel. The conduit would terminate at a control house located at the downstream portal of the tunnel, wherein releases would be further regulated by a 60-inch diameter needle valve. Access to the pipe and intake structure would be maintained through the diversion tunnel.

For the dam with height of 140 feet, an intake structure similar to those for the two larger dams was planned. However, the outlet conduit would follow an alignment along the contour of the bedrock on the left abutment. The conduit would be constructed of reinforced concrete, horseshoe in section, and



9.5 feet in diameter, and would be placed in a trench excavated to sound rock. A 60-inch diameter steel outlet pipe, supported on ring girders, would be placed within this concrete conduit. The outlet pipe would terminate at the downstream toe of the dam in a control house. Further regulation of reservoir releases would be obtained by installing a 54-inch diameter needle valve in the pipe line. Access to the pipe and intake structure would be maintained through the outlet conduit.

Based upon field examination, it was estimated that, depending upon the height of dam to be constructed, from 1,030 to 1,490 acres of light brush and some trees would have to be removed from the reservoir area. The cost of acquisition of private lands, and improvements on private and public lands was estimated by the Ventura County Flood Control District in 1952 to be about \$446,650. In 1952, the United Water Conservation District estimated the cost of necessary road relocation to be about \$150,000, and oil well damages to be about \$200,000.

Presented in Table 101 are pertinent data with respect to the general features of the three sizes of dams and reservoirs considered at the Santa Felicia site, as designed for cost estimating purposes. For illustrative purposes, a plan, profile, and section for the dam creating a reservoir with storage capacity of 100,000 acre-feet are shown on Plate 34, entitled "Santa Felicia Dam on Piru Creek".

TABLE 101

GENERAL FEATURES OF THREE SIZES OF DAM AND RESERVOIR  
AT THE SANTA FELICIA SITE ON PIRU CREEK

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Earthfill Dam

Crest elevation, in feet, U.S.G.S. datum	1,030	1,055	1,077
Crest length, in feet	1,040	1,160	1,240
Crest width, in feet	30	30	30
Height, spillway lip above stream bed, in feet	140	165	187
Side slopes, upstream and downstream	2.5:1	3:1	3:1
Freeboard, above spillway lip, in feet	20	20	20
Elevation of stream bed, in feet, U.S.G.S. datum	870	870	870
Volume of fill, in cubic yards	3,037,900	4,527,000	5,428,000

Reservoir

Surface area at spillway lip, in acres	884	1,066	1,280
Gross storage capacity at spillway lip, in acre-feet	50,000	75,000	100,000
Type of spillway	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute	Ogee weir and concrete lined chute
Spillway discharge capacity, in second-feet	103,000	103,000	103,000
Type of outlet	60-inch diameter steel pipe, in reinforced concrete conduit beneath dam	72-inch diameter steel pipe, through diversion tunnel	72-inch diameter steel pipe, through diversion tunnel

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Presented in Table 102 is a summary comparison of capital and annual costs of the three considered sizes of dam and reservoir at the Santa Felicia site. Also presented in Table 102 are estimated unit costs of storage capacity and net safe yield of water that would be developed by construction of the three sizes of reservoir. Yields referred to are those that would result under the uniform release method of reservoir operation with releases for maintenance of historic ground water levels. Certain of the relationships presented in Table 102 are depicted graphically on Plates 35, 36, and 37. Detailed estimates of cost for the three sizes of dam and reservoir at the Santa Felicia site are included in Appendix C.

TABLE 102

SUMMARY OF ESTIMATED COSTS OF DAMS, RESERVOIRS, AND YIELDS OF WATER AT SANTA FELICIA SITE ON PIRU CREEK

Item	Reservoir storage capacity, in acre-feet		
	:	:	:
	50,000	75,000	100,000
Capital Costs			
Dam and reservoir	\$ 7,128,000	\$ 8,417,000	\$ 9,029,000
Cost per acre-foot of storage	143	112	90
Cost per acre-foot of net safe yield	1,080	765	600
Annual Costs			
Dam and reservoir	369,000	435,000	469,000
Cost per acre-foot of net safe yield	56	40	31
Cost per acre-foot of incremental net safe yield	---	15	8



## Conveyance and Distribution of Supplemental Water

This section describes the various conveyance and distribution systems that were considered for delivery of locally developed supplemental water to areas of need in Ventura County, and presents preliminary cost estimates thereof. The location and alignment of the systems studied are shown on Plate 42, entitled "Proposed Conveyance and Distribution Systems". In general, preliminary design of the conveyance and distribution systems was made by the use of available U.S.G.S. topographic maps, at a scale of 1:24,000 and with a contour interval of 20 feet, and from information obtained during field reconnaissance of the proposed routes. In most cases, design of the systems was limited to the main laterals extending to strategic points in each of the hydrologic units, and no attempt was made to estimate the cost of connection with individual water users. Except as noted, preliminary estimates of cost acquisition of right of way and relocation of existing facilities, when necessary, were made on the basis of field examination and appraisal during the course of the investigation.

Distribution System for Casitas Reservoir. In the preliminary design for a distribution system to serve water developed by Casitas Reservoir, it was assumed that sufficient reservoir storage capacity would be constructed to provide new water in an amount equal to the estimated present supplemental water requirement in the Ventura Hydrologic Unit, of about 4,000 acre-feet per season, plus an allowance to provide for a portion of the probable ultimate supplemental water requirement of about 31,000 acre-feet per season. It was assumed that the initial distribution system from the reservoir would deliver about 13,360 acre-feet of water per season, distributed in accordance with the following tabulation:

<u>Hydrologic Subunit</u>	<u>Seasonal delivery of water, in acre-feet</u>
Upper Ojai	760
Ojai	1,200
Upper Ventura River	3,320
Lower Ventura River	6,920
Rincon	<u>1,160</u>
TOTAL	13,360

The amounts shown in the tabulation may be compared with values for present and probable ultimate supplemental water requirements in the Ventura Hydrologic Unit presented in Tables 47 and 48.

In November, 1951, the Ventura County Flood Control District prepared a report entitled "Distribution of Water Stored in Casitas Reservoir and Matilija Reservoir to Lands and Users in the Year 1975", describing a distribution system for water from Casitas Reservoirs. In accordance with the request of the Board of Supervisors of the Ventura County Flood Control District, this report was reviewed by the Division of Water Resources and the results of the review were submitted to the District on June 30, 1952. The distribution system described herein conforms in general alignment to the plan prepared by the Ventura County Flood Control District, and is based on surveys, appraisals, and designs made by that District. However, certain revisions were made in line capacities and estimates of cost. The locations of Casitas Reservoir and the distribution system therefrom are shown on Plate 42.

From the outlet control house at Casitas Dam, the main feeder line of the distribution system would follow Casitas Pass Road generally downstream along the right bank of Coyote Creek, and would connect with the Foster Park intake of the City of Ventura's water system. This feeder line would convey the entire supply from the reservoir for the Upper Ojai, Ojai, and Upper and Lower Ventura River Subunits. It would have a discharge capacity of about 32 second-feet, and would

be capable of delivering about 2,000 acre-feet per month. This amount represents about 15 per cent of the assumed seasonal supply available from the reservoir, which is somewhat greater than the estimated maximum monthly percentage of seasonal demand for water in the Ventura Hydrologic Unit. By designing the main feeder and laterals under this criterion, some additional peaking capacity was obtained. The main-feeder line to Foster Park would be about 14,000 feet in length, and would be constructed of 36-inch diameter centrifugal spun reinforced concrete pipe.

From Foster Park, a smaller line would extend northerly a distance of about 9,000 feet to the vicinity of Lacrosse, where a wye would be installed. This 27-inch diameter reinforced concrete cylinder pipe would have a capacity of about 14 second-feet, and would deliver about 5,280 acre-feet per season.

From the wye near Lacrosse, one branch line would continue northerly about 18,000 lineal feet generally parallel to the Ventura River to State Highway 150, where another wye would be located. This line would consist of a 24-inch diameter reinforced concrete pipe with a capacity of 10 second-feet, and would deliver a seasonal supply of about 3,750 acre feet. A regulatory reservoir of about 50 acre-foot storage capacity would be located north of Oak View on the line. It was assumed that a pumping plant, required on this line to lift the water about 350 feet, would consist of three pumps installed in series, each with a 200 horsepower motor.

From the wye near Lacrosse, a second line would extend northeasterly along San Antonio Creek, a distance of about 42,800 feet to a regulating reservoir, about 1.8 miles easterly from the town of Ojai at an elevation of 880 feet. This line would consist of a 16-inch diameter reinforced concrete cylinder pipe with capacity of 4.0 second-feet, and would deliver a seasonal supply to the regulating reservoir of about 1,525 acre-feet. It was assumed that two pumping plants would be utilized on this line, each equipped with a 100 horsepower motor and each lifting the water about 310 feet.



From the wye at State Highway 150, one line would extend westerly across the Ventura River about 13,400 lineal feet to a regulating reservoir of 50 acre-foot storage capacity in the Santa Ana Creek watershed. This 14-inch diameter reinforced concrete cylinder pipe, with capacity of about 3.5 second-feet, would deliver a seasonal supply of about 1,315 acre-feet to the regulating reservoir at an elevation of 665 feet.

From the wye at State Highway 150, another conduit would extend about 1,400 lineal feet to a point immediately north of Meiners Oaks, where an interconnection would be made with the existing pipe line from Matilija Reservoir. This 6-inch diameter reinforced concrete cylinder pipe, with capacity of about 4.5 second-feet, would deliver a seasonal supply of about 1,700 acre-feet. It was assumed that a pumping plant, required on the line to lift the water about 360 feet, would consist of three pumps, each equipped with a 120 horsepower motor.

From the aforementioned regulating reservoir easterly of Ojai, a line would extend northerly to provide an additional interconnection with the existing Matilija pipe line. This lateral would consist of about 4,500 lineal feet of 12-inch diameter reinforced concrete cylinder pipe, with a capacity of about 1.2 second-feet, and would deliver a seasonal supply of about 450 acre-feet. From the same regulating reservoir, another conduit would extend easterly about 10,200 lineal feet to serve the Upper Ojai Subunit. This 12-inch diameter reinforced concrete cylinder pipe, with capacity of about 2.0 second-feet, would deliver a seasonal supply of about 760 acre-feet, and would terminate at an elevation of 3,312 feet in a small terminal reservoir. It was assumed that a pumping plant, required in this line to lift the water about 450 feet, would consist of two pumps connected in series, equipped with 100 horsepower and 50 horsepower motors, respectively.

From the terminus of the existing Matilija pipe line, a new line would extend northeasterly about 9,000 lineal feet to a regulating reservoir of about 40 acre-foot storage capacity at an elevation of 1,300 feet. This 10-inch diameter welded steel pipe, with capacity of about 1.2 second-feet, would deliver a seasonal supply of about 450 acre-feet. A pumping plant, required on the line to lift the water about 420 feet, would consist of two pumps installed in series, equipped with 50 horsepower and 25 horsepower motors, respectively.

Immediately west of Ojai, an extension from the existing Matilija pipe line would be constructed northerly about 5,000 lineal feet to a regulating reservoir of 40 acre-foot storage capacity at an elevation of 980 feet. This 14-inch diameter reinforced concrete cylinder pipe, with capacity of about 4.4 second-feet, would deliver a seasonal supply of about 1,640 acre-feet.

From the Foster Park intake of the City of Ventura, a pipe line would be constructed southerly to Canada Larga and thence northeasterly along Canada Larga. This would consist of about 29,200 lineal feet of 6-inch diameter welded steel pipe with capacity of about 0.5 second-feet, and would deliver a seasonal supply of about 175 acre-feet. A pumping plant, required to lift the water about 400 feet to an elevation of 760 feet, would consist of two pumps, installed in series equipped with 10 horsepower and 20 horsepower motors, respectively.

Commencing at the outlet control house at Casitas Dam, a pipe line would extend westerly along the relocated Casitas Pass Road to Casitas Summit, a distance of about 1,300 feet, and thence southwesterly to the ocean at Sea Cliff, a distance of about 21,000 feet. From Sea Cliff, one lateral would extend along the ocean a distance of about 45,000 feet to the Ventura River, and another would extend westerly a distance of about 20,000 feet to the vicinity of the County line near Rincon Point. This system would be constructed of welded steel

pipe, with the main conduit and the lateral to the Ventura River having 10-inch diameters, and the westerly lateral having an 8 inch diameter. The main conduit, with capacity of 3.0 second-feet, would deliver a seasonal supply of about 1,160 acre-feet. Capacities of the lateral to the Ventura River and of the westerly lateral would be about 2.0 and 1.0 second-feet, respectively. A pumping plant, required to lift the water about 1,000 feet to an elevation of 1,375 feet at Casitas Summit, would consist of three pumps installed in series, each equipped with a motor of 150 horsepower.

The capital cost of the distribution system for Casitas Reservoir was estimated to be about \$2,954,000. The annual costs, including interest on and amortization of the capital investment, operation and maintenance, replacement, and electrical energy charges for pumping, were estimated to be about \$252,000. Detailed estimates of cost of the distribution system are presented in Appendix C.

Casitas-Oxnard Plain Diversion. In view of the fact that net safe

yields that would be developed by the considered sizes of Casitas Reservoir substantially exceed present requirements for supplemental water in the Ventura Hydrologic Unit, consideration was given to the diversion of a portion of this excess water supply to the Oxnard Plain Subunit. It was realized that ultimately the entire net safe yield available from Casitas Reservoir site would be required in the Ventura Hydrologic Unit. However, for an interim period, possibly as long as 20 years, a surplus of water would exist. For cost estimating purposes, it was assumed that for a 20-year period subsequent to the reservoir construction it would be possible to divert an average seasonal supply of 10,000 acre-feet of water from Casitas Reservoir to the Oxnard Plain Subunit for use therein.

It was assumed that the Casitas-Oxnard Plain Diversion Conduit would extend from the outlet control house at Casitas Dam in a pipe line, independent



of the one previously described for the distribution system for the Ventura Hydrologic Unit, to a terminus in a regulating reservoir north of the City of Oxnard. From the dam, the line would parallel Coyote Creek downstream, and would follow the Casitas Pass Road to Foster Park, crossing the Ventura River near the existing highway road bridge. The crossing would be in a conduit buried to a depth of 10 feet beneath the stream bed and encased in concrete. The line would then turn southerly and generally parallel the Southern Pacific Railroad tracks to the Ventura County Fair Grounds. At the fair grounds it would turn southeasterly, continue generally parallel to the Southern Pacific Railroad tracks to the Ventura Municipal Golf Course, about 3,000 feet southwest of the community of Montalvo. The line would cross the Santa Clara River at a point about one-half mile downstream from the U.S. Highway 101 bridge. The crossing would be effected in a buried conduit, encased in concrete, with 20 feet of cover. From the Santa Clara River, the line would extend to the aforementioned regulating reservoir near the intersection of Gonzales and Rose Roads, about 1.3 miles southeast of the community of El Rio. This reservoir, designated the Oxnard Reservoir, would have a storage capacity of 100 acre-feet, and a normal water surface elevation of about 85 feet.

The Casitas-Oxnard Plain Diversion Conduit would comprise a total length of about 96,300 lineal feet, consisting of about 49,000 lineal feet of 36-inch diameter, and about 47,300 lineal feet of 27-inch diameter lock joint concrete cylinder pipe. The pipe line would have a capacity of about 25 second-feet, and would deliver a seasonal supply of about 10,000 acre-feet. It would be capable of delivering about 15 per cent of the total seasonal supply in the month of maximum demand.

The capital cost of the Casitas-Oxnard Plain Diversion Conduit was estimated to be about \$1,671,000. Based upon an assumed 20-year life and a 4 per cent interest rate, annual costs were estimated to be about \$127,000,

including interest on and amortization of the capital investment, and operation and maintenance. On this basis, that portion of the average annual unit cost of water delivered through the conduit to the Oxnard Plain Subunit attributable to the costs of the conduit was estimated to be about \$12.70 per acre-foot. The proposed alignment of the Casitas-Oxnard Plain diversion is shown on Plate 42. Detailed estimates of cost of the diversion conduit are presented in Appendix C.

Santa Clara River Conduit. It has been demonstrated that to realize maximum benefit from reservoirs constructed on tributaries of the Santa Clara River, the conserved waters must be conveyed to areas of need in the Oxnard Plain and Pleasant Valley Subunits in a conduit. Consideration was given, therefore, to the construction of a pipe line from Piru Creek down the Santa Clara River Valley to a terminus in the aforementioned Oxnard Reservoir near El Rio. The general alignment of this Santa Clara River Conduit, as designed for cost estimating purposes, is shown on Plate 42. For illustrative purposes, a conduit that would extend from the proposed Devil Canyon Dam is described herein. If dams and reservoirs were to be constructed on Sespe or Santa Paula Creeks, feeder lines would be required to connect with the main conduit. Such a feeder line from Sespe Creek is contemplated for the described conduit. Provision would be made for release from the conduit to meet the requirements of prior water rights, as necessary.

From the outlet works at Devil Canyon Dam to a point about 0.3 mile west of the community of Sespe Village, where a feeder line from Sespe Creek would connect with the main line, the Santa Clara River Conduit would consist of about 63,600 lineal feet of 36-inch diameter, and 26,600 lineal feet of 42-inch diameter reinforced concrete cylinder pipe. The line would extend southerly from Devil Canyon Dam along the left bank of Piru Creek for about 24,000 feet. At this point,

it would cross the creek and thence, passing though the town of Piru, would generally follow the alignment of State Highway 126 to the town of Fillmore and to Sespe Village. The conduit would cross Sespe Creek southwest of Fillmore. At all major stream crossings, the pipe line would be encased in reinforced concrete and buried under 20 feet of cover. It was assumed that the foregoing pipe line, with a capacity of 65 second-feet, would deliver a seasonal supply at its juncture with the Sespe Feeder of about 22,000 acre-feet. This capacity was based upon an assumed maximum monthly demand of about 12 per cent of the seasonal total, with an additional allowance for weekly demand peaks.

It was assumed that water released from reservoirs to be constructed on Sespe Creek, other than the Fillmore Reservoir, would be diverted into the Sespe Feeder by a concrete diversion weir of ogee section founded on bedrock at a point about 800 feet upstream from the U.S.G.S. stream gaging station on Sespe Creek near Fillmore. The weir would be 6 feet in height above stream bed and would have a crest length of about 200 feet. An intake structure, sand trap, and sluiceways, similar to those described for the Ventura River-Casitas Diversion, would be provided. The diverted water would be conveyed through a 36-inch diameter reinforced concrete cylinder pipe, about 28,800 feet in length, to the juncture with the Santa Clara River Conduit. It was assumed that the feeder line would deliver seasonal supply of about 18,000 acre-feet. It would have a capacity of 55 second-feet, based upon the previously described criteria utilized in design of the main conduit from Devil Canyon Dam.

From the point of connection with the Sespe Feeder the Santa Clara River Conduit would generally follow the alignment of State Highway 126 to the City of Santa Paula, and thence, following a generally southwesterly route along the right bank of the Santa Clara River, would cross the river near the existing diversion works of the Saticoy spreading grounds. Near these diversion



works, a bifurcation structure in the conduit would permit releases to the spreading grounds. Such releases would be controlled by two 48-inch diameter gate valves. The conduit would then extend generally along the alignment of Ditch Road to Oxnard Reservoir. From its juncture with the Sespe Feeder, the Santa Clara River Conduit would consist of about 67,500 lineal feet of 54-inch diameter, 15,000 lineal feet of 48-inch diameter, and 10,000 lineal feet of 42-inch diameter reinforced concrete cylinder pipe. The conduit would have a capacity of 120 second-feet, and would deliver a seasonal supply to Oxnard Reservoir of 40,000 acre-feet.

Presented in the following tabulation is a summary of estimated capital and annual costs of the Santa Clara Conduit. Detailed estimates of costs are presented in Appendix C.

<u>Portion of Santa Clara River Conduit</u>	<u>Estimated Costs</u>	
	<u>Capital</u>	<u>Annual</u>
Devil Canyon Dam to Sespe Creek	\$2,012,000	\$107,000
Sespe Creek to Oxnard Reservoir	2,907,000	154,000
Sespe Feeder	<u>844,000</u>	<u>47,000</u>
TOTALS	\$5,763,000	\$308,000

Oxnard Plain-Pleasant Valley Distribution System. As discussed in a later section of this chapter, it was concluded that ground water overdraft in Oxnard Plain and Pleasant Valley Basins, resulting in part from the lack of aquifer transmissibility, will necessitate the construction of a surface distribution system to serve supplemental water to certain lands in the Oxnard Plain and Pleasant Valley Subunits now supplied by pumping from ground water. There follows a description and preliminary cost estimates for a possible distribution system to serve supplemental water to about 21,600 net acres of agricultural land in the Oxnard Plain and Pleasant Valley Subunits, together with the Cities of

Oxnard and Port Hueneme, and the United States Navy Advance Base at Port Hueneme. The system would deliver a maximum seasonal supply during drought periods of about 45,000 acre-feet. The location of the lands to be served and the general alignment of the major distributaries are shown on Plate 42.

Choice of a distribution system capacity of 45,000 acre-feet per season was based on the following consideration. The total present requirement for supplemental water in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits was estimated to be about 74,000 acre-feet per season during drought periods. However, in arriving at this estimate, direct evaluation of all items of water supply to these subunits could not be made. It is entirely possible that there is a substantial contribution to the confined aquifers of the Oxnard Plain and Pleasant Valley Basins from percolation of rainfall and of the unconsumed portion of applied water. If this should prove to be the case, the estimates of supplemental water requirement should be reduced accordingly. For this reason, and in light of the determined magnitude of local supplemental water supplies that appear to be feasible of development, the initial works to distribute supplemental water in the Oxnard Plain and Pleasant Valley Subunits were designed with the capacity indicated.

In design of the distribution system, it was assumed that an irrigating head of one second-foot for every 80 acres of agricultural land would be required. From analysis of agricultural power consumption data, and the results of studies of water use practice conducted by the Division of Water Resources, it was estimated that during the month of maximum water demand about 40 per cent of the agricultural lands served would require water service at a given time. Thus, the total required capacity of the distribution system was estimated to be one second-foot for each 200 acres of service area, or about 120 second-feet in all, including a small additional allowance for peaking capacity. Lands that would be served

y the system, as designed, are largely those that were underlain by a landward gradient in the piezometric surface in the Oxnard and Fox Canyon aquifers during the drought period.

The distribution system to serve agricultural lands would commence at the Oxnard Reservoir, which is the terminus for conduits considered for supplying supplemental water to the Oxnard Plain and Pleasant Valley Subunits. It was assumed that this reservoir would have a storage capacity of about 100 acre-feet, with inside dimensions of 450 by 450 feet and a normal depth of water of 20 feet. Excavation for the reservoir would extend to a depth of 8 feet below ground surface. The excavated material would be used in a rolled earthfill embankment, forming the sides of the reservoir. This embankment would be about 14 feet in height above ground surface, with 1.5:1 side slopes and a 20-foot top width, and 2 feet of freeboard would be provided above the normal water surface. Seepage from the reservoir would be prevented by a buried asphaltic concrete membrane. Reservoir releases would be effected by a 60-inch diameter reinforced concrete cylinder pipe placed through the embankment, regulated by a slide gate at the intake of the pipe. Additional control would be obtained by a gate valve at the outlet end of the pipe.

From Oxnard Reservoir, two major laterals were considered. One line would extend westerly from the reservoir along Gonzales Road to Ventura Road, where a wye would be placed in the line. From this point, one branch would continue westerly to serve the area along the Gonzales Road, and the other branch would extend in a generally southerly direction to serve the area west of the City of Oxnard. The second major lateral would extend southerly from Oxnard Reservoir and east of the City of Oxnard, and would serve the area east of the Cities of Oxnard and Port Hueneme and generally west of Revolon Slough. An additional regulating reservoir to provide peaking capacity was considered to be



necessary on this lateral, at the intersection of Pleasant Valley and Rice Roads. This reservoir would have a storage capacity of about 50 acre-feet, and would be similar in construction to Oxnard Reservoir.

The major laterals and branches of the irrigation distribution system would be constructed generally of centrifugally spun reinforced concrete pipe, varying in diameter from 12-inches to 54-inches, and totalling 174,500 feet in length. The lines were located so that ties to existing irrigation systems served by wells would not exceed about one-half mile in length. It was estimated that about 190 such ties would have to be made to the distribution system.

In order to provide supplemental water requiring a minimum of treatment to the Cities of Oxnard and Fort Hueneme and to the United States Navy Advance Base at Port Hueneme, it was assumed that well fields would be constructed in Oxnard Forebay Basin, and that a conduit, independent of the agricultural distribution system, would be constructed to serve these entities. Supplemental water for this purpose could be discharged from the Santa Clara River Conduit to the Saticoy spreading grounds. Thus, Oxnard Forebay Basin would function as a slow sand filter for the supplemental municipal supplies.

The well fields would be located northeast of the community of El Rio, one at a site immediately west of Vineyard Avenue, and one at a site between Vineyard Avenue and Ditch Road. Each field would comprise about 20 acres of land, and would contain 8 wells. It was assumed that each well would be 18 inches in diameter and 250 feet deep, with pump bowls set at a depth of about 175 feet. The gravel packed and cased wells would be placed in two rows of four wells each, with a distance of 400 feet between wells. Each well would be equipped with a pump driven by a 75 horsepower motor. It was estimated that, with the lowest ground water levels expected to occur in this vicinity, each well would produce about 1,400 gallons of water per minute. With all wells in operation, the maximum discharge from the two fields would be about 50 acre-

feet. Wells in the two fields would connect to a common pipe line, which would extend southerly along Ditch Road to the vicinity of Oxnard Reservoir, where, a connection would be made to the reservoir so that emergency interim supplies for agricultural use could be obtained from the well fields. From Oxnard Reservoir, the pipe line would continue southerly on Rose Road for a distance of about 6,500 feet, where a lateral would extend westerly to connect with the existing distribution system of the City of Oxnard. The main line would continue southerly, thence westerly to the United States Navy Advance Base, and thence southerly to Port Hueneme. A lateral extension would also be provided to serve the American Crystal Sugar Company's factory at Oxnard. Although not included as an initial feature of the considered municipal distribution system, a lateral could be constructed to meet presently relatively minor water requirements of the naval installation at Point Mugu. The over-all length of the municipal conduit, from the well field near Ditch Road to its terminus at Port Hueneme, would be about 45,000 feet.

It was assumed that at the present time the municipal conduit would serve about 10,000 acre-feet of water per season. From the well fields to the take-off of the City of Oxnard, the pipe line would have a capacity of 40 second-feet. From this point to the take-off for the American Crystal Sugar Company, its capacity would be 30 second-feet. From this point to a take-off for the Naval Advance Base, capacity of the pipe line would be 15 second-feet. The final portion of pipe line to Port Hueneme would have a capacity of 10 second-feet.

Presented in the following tabulation is a summary of estimated capital and annual costs of the proposed distribution system for the Oxnard Plain and Pleasant Valley Subunits. Detailed estimates of cost are presented in Appendix C.

Item	Estimated costs			Average annual unit cost of supplemental water attributable to cost of distribution system, per acre-foot
	:	:	:	
	:	:	:	
	:	:	:	
	:	:	:	
	Capital	Annual		
Agricultural system, including regulating reservoirs	\$3,038,000	\$169,000		\$4.80
Municipal system, including well fields	1,318,000	94,000		9.40

Piru-Las Posas Diversion. As described heretofore, consideration was given to the operation of a Devil Canyon Reservoir, constructed to a storage capacity of 150,000 acre-feet, for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units. In this connection, estimates of cost were prepared for seven capacities of the Piru-Las Posas Diversion Conduit to convey water from Devil Canyon Reservoir to the Calleguas-Conejo Hydrologic Unit. As an alternative to Devil Canyon Reservoir as a source of water supply, studies were also made of a conduit from Blue Point Reservoir to serve the Calleguas-Conejo Hydrologic Unit. For illustrative purposes, only those studies relating to utilization of Devil Canyon Reservoir for the purpose are described herein.

From reconnaissance type estimates of cost of several possible routes, it was concluded that the most economical conduit alignment would extend from the outlet works of the dam down Piru Creek to the town of Piru, and thence would follow the right bank of the Santa Clara River to a point immediately upstream from the State Fish Hatchery. At this point the conduit would cross the Santa Clara River, and then extend up Shiells Canyon to the northerly portal of a tunnel through Oak Ridge. This tunnel would extend southerly and terminate in Happy Canyon in the East Las Posas Subunit. Alternative conduits having capacities of 40,



60, 80, 100, 125, 150, and 200 second-feet were studied. For illustrative purposes, features of the Piru-Las Posas Diversion Conduit with capacity of 80 second-feet are described herein.

Water for the conduit would be discharged through the outlet works at Devil Canyon Dam at an elevation of about 1,090 feet. From Devil Canyon Dam to the northerly portal of the Happy Camp Canyon Tunnel, the conduit would consist of about 54,800 lineal feet of 60-inch diameter, and 12,700 lineal feet of 54-inch diameter lock joint concrete cylinder pipe. At the required crossings of Piru Creek and the Santa Clara River, the conduit would be buried to a depth of 20 feet and encased in concrete. Slope of the hydraulic gradient in the pipe line would be 1.2 feet per thousand feet. The Happy Camp Canyon Tunnel would be concrete line, of horseshoe section, 7 feet in diameter, and about 13,500 feet in length. Invert elevation of the northerly portal would be about 1,005 feet, and about 990 feet at the southerly portal. Water would flow by gravity in the tunnel at a normal depth of 5.7 feet, with a velocity of 5.2 feet per second.

Presented in Table 103 are estimated capital and annual costs of the Piru-Las Posas Diversion Conduit for the seven alternative conduit sizes studied. Also shown are estimates of the proportionate average annual costs of a Devil Canyon Reservoir, with 150,000 acre-feet of storage capacity operated for joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units, deemed chargeable to the latter hydrologic unit. These costs were proportioned on the basis of the amounts of net safe yield made available to each hydrologic unit. Table 103 also shows estimated unit costs of net safe yield made available to the Calleguas-Conejo Hydrologic Unit, on the same basis.

TABLE 103

## SUMMARY OF ESTIMATED COSTS AND YIELDS OF PIRU-LAS POSAS DIVERSION CONDUIT

Discharge capacity of diversion conduit, in second-feet	Net safe yield from Devil Canyon Reservoir available to Calleguas-Conejo Hydrologic Unit, in acre-feet per season	Average annual costs						Per acre-foot of incremental net safe seasonal yield
		Capital cost of conduit	Diversion conduit	Proportional cost of Devil Canyon Reservoir	Total	Per acre-foot of net safe seasonal yield		
40	15,300	\$5,714,600	\$303,000	\$423,900	\$ 726,900	\$48	\$---	
60	17,600	6,267,000	332,300	454,500	786,800	45	26	
80	20,100	6,960,500	369,000	480,200	849,200	42	25	
100	20,800	7,384,500	391,600	486,800	878,400	42	42	
125	21,600	8,087,400	428,800	493,900	922,700	43	55	
150	22,400	8,491,000	450,100	500,700	950,800	42	35	
200	23,500	9,724,200	515,600	509,600	1,025,200	44	68	

## Planned Operation of Ground Water Storage

As described in Chapter II, certain of the major ground water basins in Ventura County are not presently utilized to the maximum practicable extent. Consideration was given to enhancement of presently developed yields of ground waters from these basins through their planned operation. Such operation would involve either the modification of present patterns of pumping or the increased use of water from the basins, or both, depending upon the individual characteristics of the basin under consideration. Development of increased yield of water through planned operation of ground water storage was determined to be the least expensive of all investigated sources of supplemental water available to Ventura County. In certain ground water basins of the County, such planned operation would result in the development of substantial quantities of new water with relatively small capital expenditures, in comparison with the costs of surface storage necessary to develop comparable amounts of supplemental water. In addition, as compared with water in surface storage, evaporation losses would be negligible, and with lowering of ground water levels through increased use of the basins, nonbeneficial consumptive use of water by native vegetation would be reduced or eliminated.

From a practical standpoint, however, there are legal considerations which must be recognized in any plan for operation of ground water storage. Under the law, an overlying user in a ground water basin has a paramount right, correlative with all other overlying users, to the reasonable and beneficial use of ground water in the basin. He is, therefore, entitled to the protection of the courts against any substantial infringement of his correlative right to the ground water which he reasonably and beneficially requires, and against any use of the ground water by an appropriator which would cause an impairment to his right. That type of planned operation of ground water storage which would involve increased use of water from the basin, and possibly that type which would



modify the pumping pattern, would result in lowering of ground water levels. The attendant inconvenience or extra expense to an overlying user would not necessarily prevent such planned operation, providing it could be shown that such inconvenience or added expense were not unreasonable.

The question of what constitutes unreasonable inconvenience or expense is not subject to exact determination. However, it may be assumed that greater energy charges resulting from increased pumping lifts would not be considered an unreasonable expense or inconvenience, as long as presently installed pumping equipment of the overlying user could continue to be utilized. A material lowering of ground water levels that would necessitate deepening of wells and replacement of pumping equipment probably would be considered unreasonable. In any actual case, these matters would have to be determined by negotiated agreement or by the courts. In the studies described herein, it was not possible with data at hand to evaluate these factors. It is believed, however, that the success of planned operation of a given ground water basin would be contingent upon the voluntary negotiation of a mutually satisfactory agreement between the overlying ground water users and the operating agency.

Described in this section are studies relating to planned operation of ground water storage in Ventura County considered from the standpoints of both independent operation of the ground water basins and their operation in conjunction with existing or proposed surface storage developments.

Ojai Basin. The total ground water storage capacity of Ojai Basin was estimated to be of the order of 70,000 acre-feet, and the maximum ground water storage depletion of record therein, occurring in the fall of 1951, was estimated to have been about 28,000 acre-feet. In the latter years of the drought period from 1944-45 through 1950-51, wells near the margin of Ojai Basin were dry. Based in

part on this fact, it was estimated that the usable storage capacity in the basin, with the present pattern of pumping, is about 10,900 acre-feet. Thus, with the present pattern of pumping only about 15 per cent of the total available ground water storage capacity is usable, and it appears that utility of the basin could be enhanced by serving the marginal areas from water supplies pumped near the center of the basin.

Although storage depletion in Ojai Basin in the fall of 1951 was about 28,000 acre-feet and there is an estimated mean seasonal net draft on the ground water of approximately 3,500 acre-feet, the basin was essentially filled in 1952. This filling was undoubtedly accelerated by percolation and use of water diverted from Matilija Reservoir during 1952, but it is probable that during a wet period and with the present net draft the basin would fill naturally. Whether or not such filling would occur with a substantially greater net draft on the basin could not be determined. It is probable however, that perennial lowering of ground water levels would not result if the pumping pattern were shifted from the margins to the center of the basin, and if the present mean seasonal net draft were not exceeded. It is indicated that, were such a plan to be put into effect, the present ground water overdraft on Ojai Basin estimated to be about 2,000 acre-feet per season, would be eliminated.

Under the plan described in the preceding paragraph, it was estimated that about 1,200 net acres of land around the periphery of Ojai Basin would require water from wells located in the central portion. It is probable that in most cases the large capital expense involved in delivering the pumped ground water, in addition to the cost of drilling new wells, would prohibit execution of the plan by individual users. Furthermore, the success of such a plan would be contingent upon the willingness of ground water users overlying the center of the basin to permit drilling and subsequent operation of wells for the purpose of delivering water to the marginal areas.



Although not planned operation of ground water storage in the sense of the preceding discussion, an alternative solution to the problem of ground water overdraft in Ojai Basin lies in the spreading and percolation of water from Matilija Reservoir in the basin or its use in the Ojai Subunit. As described previously, such spreading was done by the Ventura County Flood Control District during 1952. During wet periods, Ojai Basin probably would fill naturally with the present pattern of land use and water supply development, and spreading or use of water from Matilija Reservoir would not in itself increase the yield of the basin. However, it would accelerate recovery of ground water levels therein. During drought periods, when ground water levels in Ojai Basin would be drawn down below safe elevations, the net safe yield on Matilija Reservoir, in the estimated amount of about 1,400 acre-feet per season, could be delivered to and spread in Ojai Basin or used in the subunit. By this means, the present ground water overdraft would be substantially reduced.

With construction of a reservoir at the Casitas site on Coyote Creek, and augmentation of inflow to that reservoir by diversion of flood waters from the Ventura River, it would be possible for certain entities, including the City of Ventura, which have established rights to waters of Matilija Creek originating above the reservoir, to forego those rights in exchange for rights in water served from Casitas Reservoir. If, through negotiation, such a plan could be effected, sufficient additional water could be developed at Matilija Reservoir and delivered to the Ojai Subunit to eliminate present ground water overdraft and to provide some water for the needs of future development.

Piru, Fillmore, and Santa Paula Basins. It was stated in Chapter II that the utility of Piru, Fillmore, and Santa Paula Basins is believed to be limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basins, and that the basins are not presently utilized to the maximum practicable extent. Consideration was



given to increased use of these basins for developing supplemental water to alleviate ground water overdraft conditions in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins. Such increased use would involve the construction of well fields in the upper basins and the conveyance of water extracted therefrom to areas of need in the lower subunits. Such planned operation would result in a greater lowering of ground water levels in Piru, Fillmore, and Santa Paula Basins than would occur with the present patterns of land use and water supply development. The lowered ground water levels, in turn, would provide greater underground storage space for the capture of waters that would otherwise waste to the ocean during wet periods.

Consideration was also given to the operation of potential surface storage reservoirs on tributaries of the Santa Clara River under the uniform release method, without release of water stored therein to maintain ground water in the three basins at historic levels. Such a method of surface reservoir operation would lower ground water levels in Piru, Fillmore, and Santa Paula Basins, create greater underground storage space for the capture of otherwise waste of flood flows, and would have the effect of operating the ground water basins. Also analyzed were the effects on ground water storage of coordinated operation of Piru, Fillmore, and Santa Paula Basins with potential surface storage developments on tributaries of the Santa Clara River.

In the various studies described in this section, consideration was not given to the increased costs that would be experienced by overlying ground water users as a result of lowered ground water levels caused by planned operation of the basins. Such costs were not subject to evaluation with data at hand.

There is presented in Table 104 the results of studies of the effects of operation of various capacities of reservoirs at the Topatopa, Devil Canyon and Santa Felicia sites, on ground water storage and levels in Piru, Fillmore, and

Santa Paula Basins. The surface reservoirs were operated under the uniform release method and without the release of stored water for maintenance of historic water levels in the ground water basins. The results shown in Table 104 were determined from monthly operation studies for the base period, utilizing methods and procedures described in Chapter II. For all reservoir combinations shown, it was found that Piru, Fillmore, and Santa Paula Basins, although experiencing greater ground water storage depletions than the historical during the drought period, would nevertheless have filled during the wet period. Thus, ground water overdraft would not have resulted in either of the three basins from reductions in supply caused by reservoir operation, and the effect of the increased basin storage depletion would have been to further enhance the developed safe yield of the system. The amounts of net safe seasonal yield from Topatopa, Devil Canyon, and Santa Felicia Reservoirs, under this method of operation were shown in Tables 71 and 100, respectively.

ESTIMATED EFFECTS ON PIRU, FILLMORE, AND SANTA PAULA GROUND WATER BASINS  
OF OPERATING TOPATOPE AND SANTA FELICIA RESERVOIRS  
UNDER THE UNIFORM RELEASE METHOD DURING THE BASE PERIOD,  
WITHOUT RELEASES TO MAINTAIN HISTORIC GROUND WATER LEVELS

Reservoir storage : capacity, in acre-feet :	Ground water storage depletion in fall of 1951, in acre-feet :				Increase in ground water : storage depletion in fall : of 1951 over present : conditions, in acre-feet :				Average lowering of : ground water levels : in fall of 1951, : in feet <sup>c</sup> :				Increase in average depth to : ground water in fall of 1951 : over present conditions, : in feet :			
	: Santa : Felicia :		: Fillmore : Paula : Basin :		: Fillmore : Paula : Basin :		: Fillmore : Paula : Basin :		: Fillmore : Paula : Basin :		: Fillmore : Paula : Basin :		: Fillmore : Paula : Basin :			
	Santa Felicia	Piru Basin	Fillmore Basin	Paula Basin	Fillmore Basin	Piru Basin	Fillmore Basin	Paula Basin	Fillmore Basin	Piru Basin	Fillmore Basin	Paula Basin	Fillmore Basin	Piru Basin	Santa Paula Basin	
0	0	94,300	61,000	22,600	---	---	---	---	110	40	25	---	---	---	---	
0	100,000	110,200	67,100	29,000	15,900	6,100	6,400	6,400	130	45	35	20	5	10	10	
100,000	100,000	110,200	68,200	31,300	15,900	7,200	8,700	8,700	130	45	40	20	5	15	15	
100,000	0	94,300	62,400	24,700	0	1,400	2,100	2,100	110	40	30	0	0	5	5	
100,000	50,000	106,300	66,700	29,700	12,000	5,700	7,100	7,100	120	45	35	10	5	10	10	
100,000	75,000	108,200	67,400	30,500	13,900	6,400	7,900	7,900	125	45	35	15	5	10	10	
50,000	100,000	110,200	67,900	30,800	15,900	6,900	8,200	8,200	130	45	35	20	5	10	10	
75,000	100,000	110,200	68,000	31,000	15,900	7,000	8,400	8,400	130	45	35	20	5	10	10	
0	150,000 <sup>a</sup>	112,400	68,200	30,600	18,100	7,200	8,000	8,000	130	45	35	20	5	10	10	
100,000	150,000 <sup>a</sup>	112,400	69,300	33,000	18,100	8,300	10,400	10,400	130	50	40	20	10	15	15	
0	150,000 <sup>b</sup>	111,500	67,400	29,800	17,200	6,400	7,200	7,200	130	45	35	20	5	10	10	
100,000	150,000 <sup>b</sup>	111,500	68,500	32,100	17,200	7,500	9,500	9,500	130	45	40	20	5	15	15	



A summary of the results of studies made to determine amounts of supplemental water that would be made available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits through increased use of upstream ground water storage are presented in Table 105. These studies were conducted for the base period under four assumed conditions: (1) with no surface storage developments on tributaries of the Santa Clara River; (2) with Santa Felicia Reservoir constructed to a storage capacity of 100,000 acre-feet, and operated under the uniform release method, without releases for maintenance of historic ground water levels in Piru, Fillmore, and Santa Paula Basins; (3) with Santa Felicia and Topatopa Reservoirs each constructed to a storage capacity of 100,000 acre-feet, and with the same method of operation as in (2); and (4) with Devil Canyon Reservoir constructed to a storage capacity of 150,000 acre-feet and operated under the same criteria as in (2) both for the joint benefit of the Calleguas-Conejo and Santa Clara River Hydrologic Unit and for the sole benefit of the latter hydrologic unit.

It may be noted in Table 105 that consideration was not given to the operation of Piru Basin, other than would occur through the stated method of operating Devil Canyon and Santa Felicia Reservoirs. Examination of Table 104 indicates that the average depth to ground water in Piru Basin substantially exceeds that of both Santa Paula and Fillmore Basins. It is known that certain overlying users in Piru Basin at the present time are experiencing pumping lifts in excess of 200 feet. Because of these relatively high pumping lifts, and because of the shorter distance required to convey ground water extracted from Santa Paula and Fillmore Basins to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, further consideration was not given to planned operation of ground water storage in Piru Basin.

SUMMARY OF ANALYSES OF PLANNED OPERATION OF FILLMORE AND SANTA PAULA GROUND WATER BASINS  
DURING BASE PERIOD, WITH PRESENT PATTERNS OF LAND USE

Average seasonal draft :		New water available :		Ground water storage :		Increase in ground :		Average lowering of :		Lowering of ground :	
from ground water :		to Oxnard Forebay, :		depletion in fall of :		water storage depletion :		ground water levels :		water levels over :	
storage, in acre-feet :		Pleasant Valley Sub- :		1951, in acre-feet :		tions, in acre-feet :		in fall of 1951, :		present conditions, :	
Santa Paula : Fillmore :		units, in acre-feet :		Santa Paula : Fillmore :		Santa Paula : Fillmore :		in feet :		in feet :	
Basin :	Basin :	per season :	Basin :	Basin :	Basin :	Basin :	Basin :	Basin :	Basin :	Basin :	Basin :
With no surface reservoirs											
0	0	---	22,600	61,000	---	---	25	40	---	---	---
5,000	0	1,500	31,400	61,000	8,800	0	40	40	15	15	0
10,000	0	4,900	48,200	61,000	25,600	0	60	40	35	35	0
15,000	0	9,100	67,700	61,000	45,100	0	95	40	70	70	0
20,000	0	13,500	88,500	61,000	65,900	0	130	40	105	105	0
0	5,000	2,700	27,500	67,000	4,900	6,000	30	45	5	5	5
0	10,000	6,000	36,200	77,400	13,600	16,400	45	55	20	15	15
0	15,000	9,800	44,000	87,000	21,400	26,000	55	65	30	25	25
0	20,000	13,800	52,900	98,300	30,300	37,300	70	75	45	35	35
With Santa Felicia Reservoir of 100,000 acre-foot storage capacity, uniform release operation, with no releases for maintenance of historic ground water levels											
0	0	---	29,000	67,100	6,400	6,100	35	45	10	10	5
5,000	5,000	6,500	52,400	75,600	29,800	14,600	70	55	45	45	15
7,500	7,500	10,600	66,700	80,500	44,100	19,500	95	60	70	70	20
10,000	10,000	14,800	81,800	85,400	59,200	24,400	120	65	95	95	25
15,000	15,000	23,300	116,300	97,100	93,700	36,100	175	75	150	150	35
9,000	15,000	18,200	90,400	97,100	67,800	36,100	135	75	110	110	35
5,000	0	2,800	42,900	67,100	20,300	6,100	55	45	30	30	5
10,000	0	6,400	60,200	67,100	37,600	6,100	85	45	60	60	5
15,000	0	10,700	80,400	67,100	57,800	6,100	115	45	90	90	5
20,000	0	15,200	101,400	67,100	78,800	6,100	150	45	125	125	5
0	5,000	3,200	36,500	76,000	13,900	15,000	45	55	20	20	15
0	10,000	6,800	43,500	85,000	20,900	24,000	55	65	30	30	25
0	15,000	10,500	52,000	95,000	29,400	34,000	70	75	45	45	35
0	22,000	16,000	62,000	115,500	39,400	54,500	85	85	60	60	45
With Santa Felicia and Topatopa Reservoirs, both of 100,000 acre-foot storage capacity, uniform release operation, with no releases for maintenance of historic ground water levels											
0	0	0	31,300	68,200	8,700	7,200	40	45	15	15	5
10,000	0	6,900	64,500	68,200	41,900	7,200	90	45	65	65	5
15,000	0	11,200	84,900	68,200	62,300	7,200	125	45	100	100	5
20,000	0	15,700	106,000	68,200	83,400	7,200	160	45	135	135	5
30,000	0	25,200	129,000	68,200	106,400	7,200	195	45	170	170	5
With Devil Canyon Reservoir of 150,000 acre-foot storage capacity, uniform release operation, with no releases for maintenance of historic ground water levels											
0	0	16,000	64,500	117,000	41,900	56,000	90	85	65	65	45
0	22,000 <sup>a</sup>	16,000	65,500	118,500	42,900	57,500	90	90	65	65	50

<sup>a</sup>Operated for benefit of Santa Clara River Hydrologic Unit.<sup>b</sup>With 80 second-foot diversion to Calleguas-Conejo Hydrologic Unit.

cTo obtain average depth to ground water in fall of 1951, add 25 feet, 20 feet, and 30 feet to the figures given for average lowering of ground water levels in the Piru, Fillmore, and Santa Paula Basins, respectively.

Because of lower specific yield of the water bearing formations and smaller areal extent, ground water levels in Santa Paula Basin experience a substantially greater lowering than do levels in Fillmore Basin for a given ground water draft. This is illustrated in Table 105. It is also shown that with planned operation of Fillmore Basin and lowering of water levels therein, water levels in Santa Paula Basin are also lowered. This effect is the result of reduction in that portion of water supply to Santa Paula Basin originating in Fillmore Basin. Since the objective of planned operation of ground water storage would be to develop as much new water as possible, with a minimum lowering of water levels in the basin being pumped, it would appear that most efficient operation would occur were Fillmore Basin to be operated alone.

For the purpose of cost analysis, it was assumed that an additional seasonal ground water draft of 22,000 acre-feet would be imposed on Fillmore Basin, and that this amount of water would be conveyed to the Oxnard Forebay Subunit in the Santa Clara River conduit, described previously. It was also assumed that Devil Canyon Reservoir would be constructed to a capacity of 150,000 acre-feet, and that this reservoir would be operated under the uniform release method for the joint benefit of the Calleguas-Conejo and Santa Clara River Hydrologic Units, without releases to maintain historic ground water levels in Piru, Fillmore, and Santa Paula Basins. As shown in Table 105, new water made available to the Oxnard Forebay Subunit, by such operation would amount to about 16,000 acre-feet per season. Average ground water levels in Santa Paula and Fillmore Basins would be lowered about 65 feet and 50 feet, respectively, below the levels that would have prevailed in the fall of 1951 with present patterns of land use and water supply development.

In the estimates of cost, it was assumed that about 30 acres of presently undeveloped land near the Santa Clara River channel in the westerly portion of Fillmore Basin, in Section 12, Township 3 North, Range 21 West, would be acquired for construction of a well field. The well field site is



above the flood plain of the Santa Clara River, and is shown on Plate 42. The areal extent of the proposed field would be sufficient to allow placement of the wells at intervals great enough to eliminate substantial mutual interference during pumping periods. It was assumed that eighteen wells would be drilled, two of which would be used for standby purposes. The wells would be 18-inches in diameter, drilled to a depth of about 220 feet, and gravel packed. Each well pump would be equipped with a 75 horsepower electric motor. From examination of pump test data in Fillmore Basin, it was estimated that each well would produce a minimum of about 1,500 gallons of water per minute, or a little more than 3 second-feet of continuous flow. With 16 wells in operation, the field would be capable of producing about 3,300 acre-feet per month, or about 15 per cent of the total seasonal pumpage. Discharge from the wells would feed into a small regulating reservoir located near Willard Road, and thence into the Santa Clara River Conduit. The following tabulation presents a summary of physical features of the Fillmore Well Field and appurtenant works, as designed for cost estimating purposes:

---

Wells	
Number	18
Type	18-inch diameter, gravel packed, and cased
Average depth, in feet	220
Distance between wells, in feet	400
Pumping Plants	
Number	18
Horsepower of motors	75
Depth of bowls, in feet	150
Pump capacity	1,500 gallons per minute
Average pumping head, in feet	75
Regulating Reservoir	
Capacity, in acre-feet	10
Normal water surface elevation, in feet, U.S.G.S. datum	275

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The capital cost of the Fillmore Well Field and appurtenances was estimated to be about \$338,000, including cost of the regulating reservoir. The annual costs, including interest and amortization, operation and maintenance charges, replacement, and power charges, were estimated to be about \$55,000. It was estimated that the cost of new water available for conveyance to the Oxnard Forebay Subunit would be about \$3.50 per acre-foot. These costs do not include any compensation for unreasonable expense to overlying ground water users in Fillmore and Santa Paula Basins, resulting from the planned operation of Fillmore Basin. It is not believed that, with the aforementioned increased ground water level lowering of 65 feet and 50 feet, in Santa Paula and Fillmore Basins, respectively, any such unreasonable expense would occur.

Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins. It was shown in Chapter II that with the present pattern and rate of pumping from Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins, ground water storage depletion in Oxnard Forebay Basin must be limited to about 20,000 acre-feet to prevent formation of a trough in the piezometric surface in the Oxnard aquifer, and to prevent the intrusion of sea water to the aquifer. It appears that a trough also will form in the Fox Canyon aquifer if ground water storage in Oxnard Forebay Basin is depleted in excess of 20,000 acre-feet. The Oxnard and Fox Canyon aquifers apparently lack capacity to transmit water from the forebay to the pressure areas at sufficient rates to meet the demands of present pumping drafts. For this reason, consideration was given to modification of the present pattern of ground water pumping, so that lands near the coastal front would be served with water pumped from Oxnard Forebay Basin and conveyed thereto by surface conduit. In effect, an artificial surface conveyance unit of adequate capacity would be substituted for the presently utilized natural aquifers of inadequate conveyance capacity.

Under certain conditions, such a change in pumping pattern could eliminate the threat of sea-water intrusion to a confined aquifer. In the case of the three basins under consideration, however, there are several factors which appear to make such a plan infeasible. Without some provision for supplying Oxnard Forebay Basin with an additional water supply during drought periods, it is indicated that ground water levels in the basin would be drawn down below sea level. This would take place regardless of any modification in the pattern of pumping from the three basins. Cessation of ground water pumping near the coast, particularly in the vicinities of submarine canyons near Port Hueneme and Point Mugu, would tend to mitigate the immediate threat of loss of aquifer utility through sea-water intrusion. Nevertheless, from consideration of studies described in Chapter II, it appears that a trough would still form in the Oxnard aquifer, and that under conditions of longer and more severe droughts than that from 1944-45 through 1950-51, and with increased water supply utilization in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, sea water might invade portions of the Oxnard and Fox Canyon aquifers still being actively pumped. Thus, regardless of instituted changes in the pattern of pumping from the three ground water basins, the threat of sea-water intrusion can only be eliminated with the development of supplemental water and its delivery to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, during periods of drought.

With the development of supplemental water, either in upstream surface or ground water reservoirs, and conveyance of the water to the Oxnard Forebay Subunit, either by conduit or by natural channel of the Santa Clara River, two possible methods for its distribution in the Oxnard Plain and Pleasant Valley Subunits were given consideration: (1) Utilization of Oxnard Forebay Basin as a regulating reservoir, and conveyance of the supplemental water to and its distribution in areas of need by means of the presently utilized natural aquifers;



and, (2) conveyance of the supplemental water to and its distribution in areas of need by means of a surface distribution system similar to that described under the section of this chapter entitled "Conveyance and Distribution of Supplemental Water".

Under the first of the foregoing methods of conveyance and distribution, the present pattern of pumping ground water from the three basins would not be modified. However, to eliminate the problem of inadequate aquifer transmissibility, it would be necessary to maintain ground water levels in Oxnard Forebay Basin at 60 feet above sea level or higher, in order to maintain a seaward gradient in the piezometric surface of the Oxnard aquifer and to prevent formation of a trough therein. As stated, this would limit ground water storage depletion in Oxnard Forebay Basin to about 20,000 acre-feet. If these criteria could be met, such a plan of conveyance and distribution of supplemental water would be the least expensive to put into effect. However, studies described elsewhere in this chapter indicate that insufficient water can be developed either in upstream surface or ground water reservoirs to maintain ground water levels in Oxnard Forebay Basin at the prescribed elevation. Furthermore, with maintenance of ground water levels in Oxnard Forebay Basin at an elevation of 60 feet or higher, utility of the basin as a natural regulator of surface runoff in the Santa Clara River would be almost entirely destroyed. In addition, it was estimated that a substantial portion of the supplemental water supply stored in Oxnard Forebay Basin would be lost for beneficial use through increased subsurface outflow to the ocean. For these reasons, it was concluded that conveyance and distribution of supplemental water in areas of need in the Oxnard Plain and Pleasant Valley Subunits should be accomplished through the construction of a surface conveyance and distribution system. A description of general features and the estimated costs of such a system have been presented previously in this chapter.

Simi and East and West Las Posas Basins. Although it was estimated

that there is little opportunity for further conservation of local water supplies in the Calleguas-Conejo Hydrologic Unit, studies of the Division of Water Resources and of the Soil Conservation Service of the United States Department of Agriculture indicated that presently dewatered ground water storage capacity in the Simi and East and West Las Posas Basins could be utilized to regulate imported water supplies. Utilization of these basins for such purpose would involve the construction of spreading facilities in areas where the soil profile is of such character as to allow rapid infiltration of water applied on the surface, and where no continuous underlying impervious strata exist that would prevent water applied on the surface from reaching pumped aquifers. Furthermore, there would have to be adequate carry-over storage capacity available in the dewatered portions of the basins to satisfactorily regulate the imported water.

During 1951 and 1952, the Soil Conservation Service conducted an investigation of possible spreading areas in Zone 3 of the Ventura County Flood Control District. This investigation included studies of infiltration rates and investigation of soil profiles to determine the suitability of various areas for spreading. The results of these studies have been published in a report entitled "Ground Water Replenishment by Penetration of Rainfall, Irrigation, and Water Spreading in Zone 3, Ventura County Flood Control District, California", dated April, 1953. Although the studies encompassed most of the Calleguas-Conejo Hydrologic Unit and a portion of the Pleasant Valley Subunit of the Santa Clara River Hydrologic Unit, the ensuing discussion of their results refers only to the Simi and East and West Las Posas Basins, wherein it was concluded the most favorable geologic conditions prevail for the spreading, infiltration, and storage of supplemental water.

The Soil Conservation Service estimated that there were about 725 acres of land overlying Simi Basin suitable for water spreading purposes. Of this area, it was concluded that about 590 acres would have a continuous infiltration capacity of about one foot of depth of water per day, and that about 135 acres would have a continuous capacity of about two feet of depth of water per day. In East Las Posas Subunit, about 2,320 acres of land were estimated to have a continuous infiltration capacity of about one foot of depth of water per day, with 2,480 acres having a capacity of about two feet of depth of water per day. Locations of these areas are shown on a plate in the foregoing report.

In Simi Basin, it was estimated that there were about 51,000 acre-feet of dewatered ground water storage capacity in the fall of 1951 between ground water levels prevailing at that time and a depth of 25 feet below ground surface. Similar estimates could not be made for the several aquifers in East and West Las Posas Basins, although the total dewatered storage capacity therein in the fall of 1951 was probably in the order of magnitude of that in Simi Basin.

As described earlier in this chapter, consideration was given to the utilization of Devil Canyon Reservoir with a storage capacity of 150,000 acre-feet, for the joint benefit of both the Santa Clara River and Calleguas-Conejo Hydrologic Units, and with diversion of a portion of the conserved water to the Calleguas-Conejo Hydrologic Unit through the Piru-Las Posas Conduit. It was indicated that the most economical capacity of this conduit would be about 80 second-feet. It was estimated that to equalize the discharge from an 80 second-foot conduit about 140,000 acre-feet of regulatory storage capacity would be required in the Calleguas-Conejo Hydrologic Unit. Regulation of the supplemental water supply could be effected either in surface storage or in ground water storage. Reconnaissance type investigation indicated that the cost of constructing such storage capacity in surface reservoirs would be prohibitive. Therefore, consideration was given to construction of water spreading facilities and obtaining the required regulation in ground water storage.



For cost estimating purposes, it was assumed that 30 second-feet of water spreading and infiltration capacity would be constructed in the Simi Subunit, and that 50 second-feet of such capacity would be constructed in the East Las Posas Subunit. With a Piru-Las Posas Conduit of 80 second-foot discharge capacity, an average supplemental water supply of about 7,550 acre-feet per season would be made available in the Simi Subunit, and about 12,550 acre-feet per season in the East Las Posas Subunit, which amounts would be sufficient to eliminate present ground water overdrafts in Simi and East and West Las Posas Basins and to provide some water for future growth. Regulation of these supplemental supplies would require about 50,000 acre-feet and 90,000 acre-feet of storage capacity, respectively. Assuming that there would be no substantial rise in ground water levels during future wet periods, it appears that sufficient storage capacity for this purpose would be available in Simi Basin. However, whether there is 90,000 acre-feet of dewatered ground water storage capacity available in East and West Las Posas Basins is questionable.

For cost estimating purposes, it was assumed that about 70 acres of land would be acquired for spreading purposes near Dry Canyon, in the north-central portion of Simi Valley. With an infiltration capacity of one foot of depth of water per day, these proposed spreading grounds would be capable of infiltrating a continuous discharge of 30 second-feet. Similarly, about 50 acres of presently undeveloped land would be acquired in Happy Camp Canyon in the East Las Posas Subunit, near the southerly portal of the previously described Happy Camp Canyon tunnel, a feature of the Piru-Las Posas Conduit. It was estimated that these lands would have an infiltration capacity of about two feet of depth of water per day, which would allow spreading and infiltration of a continuous flow of 50 second-feet. The spreading works would consist of a series of ponds, created by earthen dikes and interconnected with culverts. Maximum depth of water in the ponds would be 5 feet, and 2 feet of freeboard would be provided.

The location of the two spreading grounds and of laterals thereto from the Piru-Las Posas Conduit are shown on Plate 42. The costs of the Dry Canyon spreading grounds and of the lateral from the Piru-Las Posas Conduit thereto were estimated to be \$266,000 and \$1,619,000, respectively, or a total of \$1,885,000. The cost of the Happy Camp Canyon spreading grounds was estimated to be \$129,400.

Geologic investigation indicated the desirability of spreading and infiltrating water in Simi Valley at a location in the vicinity of Tapo Canyon, further east than the considered spreading grounds. However, lack of head at the southerly portal of the Happy Camp Canyon Tunnel precluded conveyance of the supplemental water to Tapo Canyon, without provision for pumping.

It should be pointed out that prior to construction of spreading works at the considered site in the Simi Subunit, drilling should be undertaken to definitely ascertain its suitability. At the Happy Camp Canyon site, a refraction seismic survey conducted by the Division of Water Resources confirmed sparse geologic evidence that the Grimes Canyon member of the San Pedro formation outcropped in the alluvium, and that the site, therefore, was apparently suitable for spreading grounds from the geologic standpoint. It appears that percolation of water in the Grimes Canyon aquifer would also replenish the overlying Fox Canyon aquifer. Whether or not the rate of movement of ground water in the two aquifers would be sufficient to prevent a mound from building up beneath the Happy Camp spreading grounds, and thereby reducing the estimated spreading capacity could not be determined. If after a period of operation there were such an occurrence, construction of additional spreading grounds in the outcrop of the Fox Canyon aquifer to the west of Happy Camp Canyon would be required to equitably distribute the water throughout East and West Las Posas Basins. A similar condition could arise in the considered spreading grounds near Dry Canyon in the Simi Subunit.

It should be pointed out that artificial replenishment of the Fox anyon aquifer in East and West Las Posas Basins would also benefit Pleasant alley Basin in the Santa Clara River Hydrologic Unit. As was stated in Chapter I, it appears that there is hydraulic continuity in the aquifer between these asins, and that Pleasant Valley Basin presently receives a portion of its eplenishment by underflow from East and West Las Posas Basins through the Fox anyon aquifer.



## Plans for Importation by Means of Feather River Project

As previously described, the State-wide Water Resources Investigation, proceeding under authorization of Chapter 1541, Statutes of 1947 and under direction of the State Water Resources Board, has as its objective the formulation of The California Water Plan. The Feather River Project resulted from these State-wide studies, and was proposed as a feature of The California Water Plan. Under provisions of this project, supplemental water would be made available to meet the probable ultimate water requirements of Ventura County.

Features of the Feather River Project are described in detail in a publication of the State Water Resources Board entitled "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan", dated May, 1951. These projects were authorized and adopted by the 1951 Legislature, in an act which authorized their construction, operation, and maintenance by the Water Project Authority of the State of California. Provision was made in the authorizing act for financing construction of the proposed works through issuance and sale of revenue bonds, and through receipt of contributions from other sources. In May, 1952, the Legislature provided \$800,000 by budgetary appropriation to the Division of Water Resources for necessary investigations, surveys, and studies, and preparation of plans and specifications for the Feather River and Sacramento-San Joaquin Delta Diversion Projects. A similar appropriation in the amount of \$750,000 was made in 1953.

There is presented in this section a summary description of the foregoing projects, the estimated costs thereof based on prices prevailing in 1951, and the provisions made therein for supplying supplemental water to Ventura County. It should be mentioned that continuing studies are being made of alternative designs and locations for project features, and as a result, works

finally constructed may differ from those described herein.

The multipurpose Feather River Project contemplates construction of a gravity concrete dam, 710 feet in height above streambed, at a point on the Feather River 1.7 miles below the junction of the North and Middle Forks and 5.5 miles above the City of Oroville. The dam will have an overpour spillway. It will create a reservoir of 3,500,000 acre-foot storage capacity, and will provide a large measure of control of the runoff of the Feather River for purposes of conservation, flood control, hydroelectric power generation, and other beneficial uses. Provision will be made for a hydroelectric power plant located at the dam, of 440,000 kilowatt capacity, and for an afterbay dam, and power plant of 25,000 kilowatt capacity, located four miles downstream from the main dam. The project also includes construction of a power transmission line from the Oroville power plants to Bethany, near Tracy in San Joaquin County, and a switch yard at the terminal. A channel crossing of the Sacramento-San Joaquin Delta will be required to carry Oroville Reservoir releases from the Sacramento River to the San Joaquin River Delta, for subsequent transmission to water-deficient areas in other parts of California.

With Oroville Reservoir operated for flood control, and to supply water for all requirements in the Feather River Service Area and for prior rights in the Sacramento-San Joaquin Delta, sufficient releases could be made to supplement surplus waters in the Delta so as to permit a continuous diversion of about 3,900 second-feet from that area, or approximately 2,845,000 acre-feet per season. Under the plan proposed in the 1951 report for serving areas of deficiency, water would be diverted from the San Joaquin Delta at sea level, the point of diversion being on Old River about five miles northwest of Tracy. The water would be lifted to a canal at an elevation of 225 feet, which would parallel the Delta-Mendota Canal southerly to a point near the south line of Merced County, where a second pumping plant would lift the water to an elevation of 400 feet. The

canal would then continue southerly approximately on grade contour along the west side of the San Joaquin Valley to the Buena Vista Hills, where another pumping plant would lift the water to an elevation of 500 feet. Four additional pumping lifts, and a canal, would deliver the water at Pastoria Creek, three miles east of Grapevine at an elevation of 1,500 feet. At various points in the San Joaquin Valley, diversions would be made from the conduit to serve lands requiring supplemental water. A series of pumping lifts at Pastoria Creek would raise the water to an elevation of 3,375 feet, and to the portal of the first of two tunnels that would convey the water through the Tehachapi Mountains to a point on the divide between the Santa Clara River Basin and Antelope Valley near Quail Lake. Near this point, releases from the conduit could be conveyed via a short tunnel to a tributary of Piru Creek, and thence to service areas in Ventura County. The main conduit would continue southerly in a series of canals, tunnels, and siphons to its terminus at a tributary of the Tia Juana River in San Diego County at a distance of about 567 miles from the point of diversion in the San Joaquin Delta. En route it would serve supplemental water to lands in the Lahontan, Colorado Desert and South Coastal Areas. In connection with the delivery of water from the conduit, hydroelectric power could be developed at several points on the Pacific slope of southern California. Plate 39, entitled "Feather River Project," shows the location of Oroville Reservoir, and the general alignment of the San Joaquin Valley-Southern California Diversion conduit.

Detailed estimates of cost of the Feather River Project are included in the feasibility report, but are currently being revised. A summary of estimated capital costs of the project, as presented in the 1951 report, is given in Table 106. The estimates of capital cost were based on prices prevailing in 1951, and included allowances of 10 per cent for administration and engineering, 15 per cent for contingencies, and 3 per cent for interest during one-half of the estimated construction period.



TABLE 106

SUMMARY OF ESTIMATED CAPITAL COSTS OF  
FEATHER RIVER PROJECT AND SACRAMENTO-SAN  
JOAQUIN DELTA DIVERSION PROJECTS

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Oroville Dam and Reservoir	\$ 342,626,000
Oroville Power Plant	64,509,000
Oroville Afterbay and Power Plant	14,146,000
Oroville Transmission Line and Terminal Switchyard	19,734,000
Delta Cross Channel	3,798,000
Santa Clara-Alamada Diversion	31,065,000
San Joaquin Valley-Southern California Diversion	<u>794,509,000</u>
TOTAL	\$1,270,387,000

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It was assumed in the cost analyses presented in the feasibility report that the Federal Government would contribute to the Feather River Project the sum of \$50,000,000, without reimbursement, in the interest of flood control. Substantial flood control benefits to lands and communities along the Feather River would result from operation of the project. There is a well-established federal policy for such financial participation in projects of this character. It was also assumed that the State of California would contribute the sum of \$86,926,000 for the acquisition of lands, easements, and rights of way, and for the relocation of utilities. This contribution would also be non-reimbursable. Such financial participation by the State would be justified under the policy set forth in the State Water Resources Act of 1945, as amended. If these federal and state contributions to the Feather River Project were forthcoming, capital costs shown in Table 106 would be reduced to \$1,133,461,000.

Based on this estimated capital cost, it was further estimated with 1951 report that annual costs of the project would be about \$108,775,000 with an

assumed 2 per cent interest rate, and about \$114,539,000 with an assumed 3 per cent interest rate. The annual costs included interest repayment, replacements, operation and maintenance, power charges, insurance, and general expense. In the cost analysis, it was shown that annual costs based upon the 2 per cent interest rate could be met under the schedule of revenues shown in the following tabulation, but that an annual deficit of some \$1,898,000 would occur with the 3 per cent interest rate.

<u>Item</u>	<u>Unit Charge</u>	<u>Annual Revenue</u>
311,000 acre-feet of new water delivered to service area along Feather River	\$ 1.00	\$ 311,000
127,000 acre-feet to Santa Clara-Alameda Diversion	20.00	2,540,000
945,000 acre-feet to San Joaquin Valley	10.00	9,450,000
1,773,000 acre-feet to southern California	50.00	88,650,000
1,670,000 kilowatt-hours Terminal Substation	0.007	<u>11,690,000</u>
	Total	\$112,641,000

Based on the foregoing assumptions, the estimated cost of water from the Feather River Project available for diversion to Ventura County from the San Joaquin Valley-Southern California Diversion Conduit would be about \$50 per acre-foot.

The stated purpose of the Feather River Project is to furnish water as needed to supplement existing supplies. In the cases of both the San Joaquin Valley and southern California, it would provide supplemental rather than substitutional water for otherwise developed water supplies, including California's rights in and to the waters of the Colorado River in the amount of 5,362,000 acre-feet annually. In this connection, studies made as a part of the current State-wide Water Resources Investigation indicate that the probable ultimate

supplemental water requirements of the San Joaquin Valley and southern California will be much larger than can be met by the Feather River Project as previously described. For this reason Oroville Reservoir is considered to be only an initial storage unit in The California Water Plan, and additional reservoirs and increased conduit capacities will be provided as the demands of an increasing population dictate.

The plan of utilizing the delta of the Sacramento and San Joaquin River as a point of diversion of surplus waters developed in northern California for export to areas of need has many practical advantages. The diversion point is below all riparian owners and users of water in the basin above the delta, and therefore is not subject to objection by such owners. The delta channels are recipient of all the flood flows and return waters from an area of about 50,000 square miles. The supply to the delta, therefore, is not dependent on the vagaries of a single stream. Water developed in any part of the Sacramento or San Joaquin River basins could find its way by gravity to the delta, and the same is true of surplus water that might be transferred from the North Coastal Area to the Sacramento River Basin.

Advantages of the planned conduit to the San Joaquin Valley and southern California are that it would traverse, in large part, undeveloped terrain, would not interfere with the operation of existing water supply systems, would not involve any exchange of waters, and would be located in a position to furnish by gravity from the conduit additional water supplies to existing systems, and to new areas capable of development and in need of water. It is feasible of construction from both engineering and geological standpoints, capable of development to serve supplemental water to meet the ultimate needs of the west and southern sides of the Upper San Joaquin Valley, the South Coastal Area including Ventura County, and the desert areas in Los Angeles, San Bernardino, and Riverside Counties.



Studies are being continued to select a final alignment and grade for San Joaquin Valley-Southern California Diversion Conduit, and also to determine the most feasible manner in which supplemental water from the project could be diverted for use in Ventura County. From the results of studies described in this bulletin, it was estimated that the probable ultimate requirement for imported water in Ventura County will be in the order of 200,000 acre-feet per season, which amount could be readily supplied from the San Joaquin Valley-Southern California Diversion Conduit when operated at ultimate capacity.

For illustrative purposes, there is shown on Plate 40 a possible profile, resulting from preliminary reconnaissance, for the foregoing diversion to Ventura County. The location of this diversion should be considered as tentative, and subject to considerable modification after studies currently underway have been completed. Commencing at a turn-out from the San Joaquin Valley-Southern California Diversion Conduit, at about an elevation of 3,325 feet in the upper end of the Antelope Valley near Quail Lake, water for diversion to Ventura County would discharge into a small regulating reservoir having a normal water surface elevation of about 3,324 feet. Discharge from the reservoir would be conveyed a distance of about 8,200 feet in a southerly direction in a canal. The canal would discharge into a tunnel about 21,500 feet in length through the Piru Mountains. From the outlet of the tunnel, the conduit would consist of about 2,000 lineal feet of reinforced concrete siphon, followed by a tunnel about 4,600 feet in length, which would discharge into the penstock of Power Plant No. 1, located near Highway 99 at an elevation of about 2,480 feet. About 800 feet of power drop would be available at this plant.

Discharge from Power Plant No. 1 would enter Canada de Los Alamos, a tributary of Piru Creek, and would follow that tributary and Piru Creek to a point about 17,400 feet downstream from their confluence. At this point the flow would

be diverted to a tunnel about 11,200 feet in length, from which it would discharge into the penstock of Power Plant No. 2, located on Piru Creek about 2.6 miles upstream from the Ventura-Los Angeles County Line, at an elevation of about 1,885 feet. The power drop available at this plant would be about 370 feet.

Water from the afterbay of Power Plant No. 2 would be diverted to a tunnel about 13,900 feet in length, and thence into the penstock supplying Power Plant No. 3. This plant would be located on Piru Creek some 7.0 miles upstream from the Devil Canyon dam site, at an elevation of about 1,325 feet. Approximately 520 feet of power drop would be available at Power Plant No. 3.

Discharge from Power Plant No. 3 would enter Piru Creek and flow to terminal storage at Devil Canyon Reservoir. As previously described, this reservoir would have a storage capacity of about 150,000 acre-feet. Its normal water surface elevation would be about 1,265 feet. As an alternative to terminal regulation at Devil Canyon Reservoir, consideration was given to utilization of Blue Point Reservoir, constructed to a storage capacity of about 50,000 acre-feet for regulation of imported Feather River Project water.

Although the alignment for the diversion to Ventura County, as described, would be advantageous from the standpoint of developing hydroelectric power, revenue from the sale of which could be used in reducing costs of the imported water supply, further studies may show that construction of the several required tunnels of substantial length is unfeasible. If such should be the case, a gravity diversion to Ventura County, with a minimum of tunnel, could be effected from the foregoing regulating reservoir near Quail Lake. Discharge from the regulating reservoir would then largely follow the natural channels of Piru Creek and its tributaries to Devil Canyon Reservoir.

From Devil Canyon Reservoir, gravity service of the imported water could

be provided most areas of need in the Calleguas-Conejo, Malibu, and Santa Clara River Hydrologic Units, and a substantial portion of those in the Ventura Hydrologic Unit. A diversion to the Calleguas-Conejo and Malibu Hydrologic Units could be effected through a conduit from Piru Creek to Happy Camp Canyon, similar to that described previously. It would also be possible to supply supplemental water through this system to that portion of the Malibu Creek drainage area within Los Angeles County, including the community of Malibu and adjacent resort areas. Gravity water service could also be provided to Santa Barbara County in the vicinity of Carpenteria.



Plans for Importation by Means of  
Metropolitan Water District of Southern California

A source of supplemental water for Ventura County is immediately available in the Colorado River through the facilities of the Metropolitan Water District of Southern California. Colorado River water is now imported to the South Coastal Area by the Metropolitan Water District from Lake Havasu, an artificial reservoir on the Colorado River created by Parker Dam. The importation is made through an aqueduct about 242 miles in length to terminal storage in Lake Mathews, about nine miles southerly of the City of Riverside. From Lake Mathews the imported water is distributed to many public water service agencies in Los Angeles, San Bernardino, Riverside, Orange, and San Diego Counties.

In lieu of immediate construction of local conservation works in Ventura County, consideration was given to the annexation of Ventura County to the Metropolitan Water District of Southern California for the purpose of obtaining supplemental water to eliminate present water supply deficiencies and to provide for anticipated future water needs.

Metropolitan Water District of Southern California

The Metropolitan Water District of Southern California was organized in 1928, after the State Legislature had passed an enabling act in 1927. In 1931, when bonds in the amount of \$220,000,000 were voted for financing the Colorado River development, the District comprised 13 member cities, having a total assessed valuation of slightly less than \$2,500,000,000. As of August 20, 1953, the assessed valuation was estimated to be \$6,015,500,000, and the District comprised 13 member cities, six municipal water districts, and the San Diego County Water Authority. Actual construction on the Colorado River Aqueduct started in January, 1933. The first delivery of softened Colorado River water, from the softening and treatment plant located near La Verne, was made to the City of Pasadena in June, 1941.

The right of the Metropolitan Water District of Southern California to waters of the Colorado River, as determined under provisions of the Colorado River Compact, Boulder Canyon Project Act, and in accordance with the Seven-Party Water Agreement which was executed among interested California parties in August, 1931, is 1,112,000 acre-feet per annum, including the right of the San Diego County Water Authority of 112,000 acre-feet per annum. During 1952-53, about 162,000 acre-feet, or 14.6 per cent of the foregoing entitlement of the District to Colorado River water, were sold by the District.

Section 5-1/2 of the Metropolitan Water District Act provides as follows:

"Each city, the area of which shall be a part of any district incorporated hereunder, shall have a preferential right to purchase from the district for distribution by such city, or any public utility therein empowered by said city for the purpose, for domestic and municipal uses within such city a portion of the water served by the district which shall, from time to time, bear the same ratio to all of the water supply of the district as the total accumulation of the amounts paid by such city to the district on tax assessments and otherwise, excepting purchase of water, toward the capital cost and operating expense of the district's works shall bear to the total payments received by the district on account of tax assessments and otherwise, excepting purchase of water, toward such capital cost and operating expense."

The preferential right of a member to available water, therefore, is proportional to the ratio of total tax payment actually made by that member to the total tax payments actually made by all members of the District. Thus, a newly annexed area would have an entitlement based only on the taxes actually paid to the District. However, entitlements so determined do not at the present time limit the quantities of water that may be obtained from the District, but would be effective when utilization of water by the District equals the ultimate capacity of Colorado River Aqueduct, if no other water supply is made available in the meantime.

Procedure for annexation of Ventura County to the Metropolitan Water District would include formation of a public district with appropriate powers

and embracing the entire County. If such a district were formed, the assessed valuation of the County would be used in estimating entitlements to water under the preferential right principle, and Ventura County's share in the Colorado River water supply would be determined thereby. In order to estimate the quantity of water to which Ventura County would be entitled, with the Colorado River aqueduct operating at its ultimate capacity, the entire Colorado River supply in use, and disregarding losses, it was assumed the ratio of Ventura County's assessed valuation to that of the entire Metropolitan Water District, including that of Ventura County over a 40-year period commencing in 1929, would be proportional to the estimated 1953-54 ratio of \$306,000,000 to \$6,321,500,000. By multiplying the District's entitlement of 1,212,000 acre-feet per season of Colorado River water by this ratio, it was indicated that Ventura County would be entitled to a water supply of about 59,000 acre-feet per season under the stated conditions.

It is apparent that the foregoing supplemental water supply would be inadequate to meet present requirements in Ventura County. However, in this regard, the following statement of policy by the Metropolitan Water District's Board of Directors on December 16, 1952, is considered pertinent:

"The Metropolitan Water District of Southern California is prepared, with its existing governmental powers and its present and projected distribution facilities, to provide its service area with adequate supplies of water to meet expanding and increasing needs in the years ahead. The district now is providing its service area with a supplemental water supply from the Colorado River. When and as additional water resources are required to meet increasing needs for domestic, industrial, and municipal water, the Metropolitan Water District of Southern California will be prepared to deliver such supplies.

"Taxpayers and water users residing within The Metropolitan Water District of Southern California already have obligated themselves for the construction of an aqueduct supply and distribution system involving a cost in excess of \$350,000,000. This system has been designed and constructed in a manner that permits orderly and economic extensions and enlargements to deliver the district's full share of Colorado River water as well as water from other sources as required in the years



ahead. Establishment of overlapping and paralleling governmental authorities and water distribution facilities to service Southern California areas would place a wasteful and unnecessary financial burden upon all the people of California, and particularly the residents of Southern California."

This policy statement may be interpreted in light of recent developments relating to importation of supplemental water to southern California, which have been described hereinbefore under the section entitled "Plans for Importation by Means of Feather River Project".

Untreated Colorado River water, which has been considered for importation to Ventura County, is of acceptable mineral quality for irrigation use. Total mineral solubles in the supply delivered to the Metropolitan Water District's system have averaged between 750 and 800 parts per million during the past five years. The water has a low concentration of boron, and a moderate percentage of sodium ion. However, the concentrations of total mineral solubles are such that some soil types to which the water might be applied would require adequate leaching to prevent excessive accumulation of minerals. For domestic use, Colorado River water would require chlorination, as do practically all raw waters. Softening treatment would enhance its suitability for such use. A typical analysis for constituent characteristics of Colorado River water, related to its domestic use, is presented in the following tabulation:

Total hardness, as parts per million of	
CaCO <sub>3</sub> . . . . .	334
Non-carbonate hardness, as parts per	
million of CaCO <sub>3</sub> . . . . .	215
Alkalinity, as parts per million of CaCO <sub>3</sub> . . .	119
Magnesium, as parts per million . . . . .	30
pH. . . . .	8.3

As a matter of interest, it may be noted that the mineral quality of Colorado River water compares favorably with that of local supplies throughout Ventura County.

## Conveyance of Imported Water to Ventura County

Discussion with engineers of the Metropolitan Water District has indicated that the nearest source of Colorado River water for Ventura County would be a take-off point on a conduit currently being considered for construction from Lake Mathews to Orange County, designated the "Lower Orange County Feeder". Although final alignment of this conduit has not been fixed, for cost estimating purposes it was assumed that it would follow the general alignment shown on Plate 25, and that the take-off for Ventura County would be in Walnut Canyon about 10 miles southeast of the City of Fullerton.

The assumed elevation of Lower Orange County Feeder at the take-off for Ventura County was taken as 940 feet. From this initial point, preliminary consideration was given to three possible conduit routes to Ventura County. These routes were as follows: (1) westerly to the coast, and thence northerly along U. S. Highway 101 Alternate to the coastal plain of the Santa Clara River valley; (2) northwesterly to the vicinity of Glendale, and thence along U. S. Highway 101 to Conejo Valley; and (3) northwesterly to the vicinity of Glendale, and thence across San Fernando Valley to Chatsworth and to Simi Valley. It was determined that gravity supply could be obtained at the Oxnard Plain utilizing the first of the foregoing routes. The second and third routes considered would require pumping. The third route, in addition to the pumping installations, could require a tunnel through the Santa Susana Mountains into Simi Valley. Reconnaissance type estimates of cost indicated that to reach a common terminal storage site in Ventura County, which would be required to obtain maximum utility of such a conduit, there would be little difference in cost of the three routes. However, the third route would be the most favorable from the standpoint of distribution of water in the Calleguas-Conejo Hydrologic Unit. This latter route, therefore, was chosen to illustrate the costs of delivering Colorado River

water for use in Ventura County. The conduit for conveying Colorado River water to Ventura County is hereinafter referred to as the Ventura County Aqueduct.

Preliminary estimates of cost were prepared for conduits with capacities of 25, 50, 75, 100, and 150 second-feet, respectively. Commencing at the aforementioned point on the proposed Lower Orange County Feeder, at an elevation of 940 feet, the Ventura County Aqueduct would extend generally in a northwesterly direction, a distance of about 438,800 feet or about 83 miles, to terminal storage at the Conejo reservoir site on Conejo Creek. It would include about 15,200 lineal feet of tunnel through the Santa Susana Mountains at an elevation of 1,077 feet.

From the take-off, the line would extend northwesterly down Walnut Canyon, and would cross beneath the Santa Ana River bed at station mile 3. From the river, it would extend northwesterly through the town of Yorba Linda and pass northeast of the town of Brea, to Whittier Boulevard at station mile 13. From this point the aqueduct would parallel Whittier Boulevard, passing through the City of Whittier, and crossing the San Gabriel River at station mile 24. At station mile 25, it would turn northerly to Beverly Boulevard, and then proceed westerly along that boulevard, crossing the Rio Hondo at station mile 26. At station mile 28 the aqueduct would leave Beverly Boulevard and extend northwesterly through the City of Los Angeles, crossing the Arroyo Seco at station mile 36.

From the Arroyo Seco, it would follow the alignment of San Fernando Road through Glendale to station mile 42, where it would turn westerly, following the left bank of the Los Angeles River to station mile 45. At this point, the aqueduct would turn northwesterly and pass through the City of Burbank, to Burbank Boulevard at station mile 48, and then continue westerly along the alignment of Burbank Boulevard, passing beneath the improved channel of Tujunga Wash at station mile 50, to Fulton Avenue at station mile 52.



From the intersection of Fulton Avenue and Burbank Boulevard, the conduit would extend northerly to station mile 52, where Pumping Plant No. 1 could be located. From this plant, the aqueduct would continue northerly to Roscoe Boulevard at station mile 55. From the intersection of Fulton Avenue and Roscoe Boulevard, it would extend westerly along Roscoe Boulevard to station mile 66, where Pumping Plant No. 2 would be located, at a site about one mile south of Chatsworth Reservoir. From this plant, the conduit would continue westerly along Roscoe Boulevard to station mile 67, where it would turn northwesterly at Dayton Canyon, following the North Fork of Dayton Canyon to the southeasterly portal of the aforementioned Santa Susana Tunnel at station mile 68.

The northwesterly portal of the Santa Susana Tunnel would be on the southerly side of Simi Valley, about 1.5 miles southeast of the town of Santa Susana. From this portal, the aqueduct would extend westerly along the south side of Simi Valley to station mile 77, where a take-off for the Oak Canyon Terminal Reservoir would be located. Continuing westerly, the conduit would cross a saddle between the Calleguas and Conejo Creek drainage areas at an elevation of about 980 feet, and would terminate at a tributary of the North Fork of Conejo Creek at about station mile 83. From this point, water discharged from the aqueduct would follow the natural watercourse to terminal storage at Conejo Reservoir. The proposed Conejo Dam would be at station mile 86.

For illustrative purposes, there are described herein design features for a Ventura County Aqueduct having a discharge capacity of 150 second-feet. Plate 41, entitled "Profile of Proposed Ventura County Aqueduct to Connect with System of Metropolitan Water District of Southern California - Capacity 150 Second-feet" shows a profile of this conduit from Walnut Canyon to Conejo Reservoir. Design features of the other conduit capacities considered would be similar in all respects except size. The conduit with discharge capacity of 150 second-feet would comprise about 414,800 lineal feet of 72-inch diameter, about 5,000 lineal

feet of 42-inch diameter, and about 3,800 lineal feet of 36-inch diameter lock joint concrete cylinder pipe. The 72-inch diameter pipe would extend from the take-off at Walnut Canyon to the saddle between the Calleguas and Conejo Creek drainage areas, from which point the smaller size pipes would be installed to dissipate pressure head prior to discharging into the natural watercourse. Velocity in the 72-inch diameter pipe would be about 5.3 feet per second, and the slope of the hydraulic grade line would be about 0.001. Maximum pressure head in the conduit would be about 600 feet at a point near the San Gabriel River crossing.

Releases to the Ventura County Aqueduct from the Lower Orange County Feeder would be effected by a bifurcation structure with gate valve regulation. Throughout its length, the conduit would be buried with a minimum cover of 4 feet. At major unimproved stream crossings, the conduit would have a cover of 20 feet and would be encased in concrete. Automatic air release valves would be installed at all high points, with automatic blowoff valves at low points where release would discharge to a stream channel. The Santa Susana Tunnel would have a horse-shoe section, 7 feet in diameter, and would be concrete lined throughout. The slope of the tunnel invert would be 0.0009, and water therein would flow under gravity at a depth of 5.7 feet.

The two pumping plants required on the main conduit would have identical facilities. Inflow to the plants would be from a small regulating reservoir on the line, installed to maintain a constant discharge and head. Each plant would be equipped with five pumping units in parallel connection. Two of the units would have capacities of 25 second-feet, and the remaining three units would have capacities of 50 second-feet. One of the larger pumping units would be used for standby purposes. Each 25 second-foot capacity unit would consist of two pumps connected in series, each equipped with a 450 horsepower motor. Each of the larger units would similarly be equipped with two pumps in series driven by 900

horsepower motors. The pumping lift at each of the plants would be about 225 feet.

The take-off for the Oak Canyon Terminal reservoir at station mile 77 would be effected by a bifurcation structure in the main conduit. The Oak Canyon lateral would be a 42-inch diameter reinforced concrete pipe about 4,000 feet in length, and would have a capacity of 40 second-feet. Pumping Plant No. 3 would be located on the right abutment of Oak Canyon Dam described hereinafter. A maximum lift of 90 feet would be required on the lateral with Oak Canyon Terminal Reservoir full. Pumping Plant No. 3 would be equipped with two 20 second-foot capacity pumps driven by a 300 horsepower motor.

#### Terminal Storage

In order to obtain the maximum utility from the Ventura County Aqueduct and to provide the peaking capacity within Ventura County, construction of two terminal storage reservoirs was considered. For illustrative purposes, reservoirs that would be required for regulation of the conduit with a capacity of 150 second-feet are described herein.

A dam, and reservoir with capacity of 7,500 acre-feet, would be constructed at the Oak Canyon site to regulate the 40 second-foot diversion from the main conduit. This water surface elevation at the spillway lip would be 1,100 feet. Water from this reservoir would be distributed in the Calleguas-Conejo Hydrologic Unit. The Oak Canyon Dam would be an earthfill structure with an impervious core and upstream and downstream sections of random fill. The dam would be 170 feet in height from stream bed to spillway lip, with upstream and downstream slopes of 2.5:1. The volume of fill would be about 1,587,000 cubic yards. The spillway would be across the right abutment, and would have a discharge capacity of 2,000 second-feet. Releases from the reservoir would be effected by means of a concrete outlet tower. A topographic map of the dam site was prepared at a scale of one inch equals 100 feet, with a contour interval of 10 feet, by the Division of Water Resources in 1953. Areas and capacities of



the reservoir for various stages of water surface elevation were determined from available U.S.G.S. quadrangles with a 40-foot contour interval.

Conejo Terminal Reservoir would provide terminal regulation and water service to the Oxnard Plain and Pleasant Valley Subunits and the Ventura Hydrologic Unit. The dam would be located on Conejo Creek near the boundary between the Santa Rosa and Conejo Subunits, and would create a reservoir with storage capacity of 20,000 acre-feet. The water surface elevation at the spillway lip would be 360 feet. The dam would be an earthfill structure with an impervious core and upstream and downstream sections of random fill. The dam would be 130 feet in height from stream bed to spillway lip, with 2.5:1 upstream and downstream slopes. The volume of fill would be about 1,655,000 cubic yards. A spillway would be across the right abutment and would have a discharge capacity of 6,000 second-feet. Releases from the reservoir would be effected by means of a concrete outlet tower. A topographic map of the dam site was prepared at a scale of one inch equals 100 feet, with a contour interval of 10 feet, by the Division of Water Resources in 1953. Areas and capacities of the reservoir for various stages of water surface elevation were determined from U.S.G.S. quadrangles with a 40-foot contour interval.

#### Distribution of Colorado River Water in Ventura County

From the Conejo Terminal Reservoir, Colorado River water could be delivered by gravity to the Oxnard Plain and Pleasant Valley Subunits, to the City of Ventura, and to the Santa Rosa Subunit. It was assumed that water supplies for the Conejo Subunit and for the Malibu Hydrologic Unit would be met initially from the main aqueduct. Water from the main aqueduct could also be served in the Tierra Rejada Subunit. Estimates were not made of works required for providing such service. The Oak Canyon Terminal Reservoir would be utilized to supply Colorado River water to all of the Calleguas-Conejo Hydrologic Unit except the Santa Rosa, Tierra Rejada, and Conejo Subunits.

As has been stated, the Oak Canyon Terminal Reservoir would regulate a continuous inflow of 40 second-feet of water from the Oak Canyon lateral, equal to a seasonal supply of about 29,000 acre-feet. It was estimated that reservoir evaporation losses would approximate 300 acre-feet per season, leaving about 28,700 acre-feet of water per season for use in the service area of the reservoir. Because of uncertainties attendant upon the development of presently undeveloped lands in the service area, conduits from the reservoir were designed to distribute this seasonal supply to strategic points in each subunit.

Deliveries to the East and West Las Posas and Simi Subunits would be effected through 42-inch diameter centrifugally spun reinforced concrete cylinder pipe, extending northerly from the reservoir to Los Angeles Avenue, where a wye would be located. From the wye, one lateral would extend westerly to the East and West Las Posas Subunits and the other easterly to the Simi Subunit. The Simi lateral would consist of about 27,000 lineal feet of reinforced concrete cylinder pipe, 30 inches in diameter, and would terminate in a regulating reservoir of 25 acre-feet storage capacity near Santa Susana. The Las Posas lateral would consist of 28,600 lineal feet of 42-inch diameter, 33,000 lineal feet of 36-inch diameter, 14,500 lineal feet of 30-inch diameter, 18,700 lineal feet of 18-inch diameter, and 2,400 lineal feet of 12-inch diameter reinforced concrete cylinder pipe. It would terminate in a regulating reservoir with storage capacity of 75 acre-feet. It was estimated that the Simi and Las Posas laterals would deliver seasonal supplies of 7,000 acre-feet and 21,700 acre-feet, respectively. It was assumed that lands lying above the laterals and requiring supplemental water would be served by pumping.

As stated, it was assumed that Colorado River water for the Conejo Subunit and the Malibu Hydrologic Unit would be taken initially from the main Ventura County Aqueduct. To this end a bifurcation structure would be placed in the aqueduct at a point about 9,000 feet from its terminus, and releases

would be made into a 30-inch diameter reinforced concrete cylinder pipe, 3,100 feet in length. This line would terminate in a regulatory reservoir of 80 acre-foot storage capacity northeasterly of Newbury Park. From this reservoir, a reinforced concrete cylinder pipe 36 inches in diameter and 14,100 feet in length, would extend southeasterly toward Newbury Park. At this point, a wye would be located, and laterals would extend westerly and easterly, respectively, therefrom. The westerly trending lateral would consist of 27,900 lineal feet of 18-inch diameter and 4,000 lineal feet of 12-inch diameter reinforced concrete cylinder pipe, and would terminate in a regulating reservoir having a storage capacity of 55 acre-feet. The easterly trending lateral would be about 19,400 feet in length, and would terminate in a regulating reservoir of about 35 acre-feet storage capacity, located just below the saddle separating the Malibu drainage area from that of Conejo Creek. Thus, water service could be provided therefrom to lands in the Malibu Hydrologic Unit. The lateral would be a reinforced concrete cylinder pipe including 7,000 lineal feet of 24-inch diameter pipe and 12,400 lineal feet of 18-inch diameter pipe. It was estimated that about 4,300 acre-feet and 2,900 acre-feet of water per season would be delivered from the westerly and easterly laterals, respectively.

Estimates of cost were made for delivery of Colorado River water from the Conejo Terminal Reservoir to Oxnard Reservoir, which water would then be utilized in the Oxnard Plain and Pleasant Valley Subunits as described in connection with plans for local conservation development. The conduit from Conejo Terminal Reservoir to Oxnard Reservoir would be lock joint reinforced concrete cylinder pipe, with a capacity of 150 second-feet. It would consist of about 73,200 lineal feet of 66-inch diameter pipe, and would deliver about 45,000 acre-feet of water per season to the Oxnard Plain and Pleasant Valley Subunits and 10,000 acre-feet per season to the Ventura Hydrologic Unit. It was assumed that water service for the cities of Oxnard and Port Hueneme would be provided from the well fields in Oxnard Forebay Basin as previously described.



This ground water draft could be replenished by Colorado River water if a lateral were provided from the conduit to the Saticoy spreading grounds. Service of Colorado River water to the City of Ventura and the Ventura Hydrologic Unit would be provided by a pipe line about 37,000 feet in length extending from a bifurcation structure in the conduit at Oxnard Reservoir. This line would terminate in a reservoir with storage capacity of 25 acre-feet at an elevation of 140 feet, located in the southeasterly portion of the City of Ventura. The line would consist of lock joint concrete cylinder pipe, 36 inches in diameter, and would have a capacity of 25 second-feet. It was estimated that the line would be capable of delivering about 10,000 acre-feet of water per season to the Ventura Hydrologic Unit. Pumping would be required if Colorado River water were to be utilized in the Upper Ojai, Ojai, or Upper Ventura River Subunits, and also in portions of the City of Ventura. Chlorination, and possible softening would be required for water used for industrial and domestic purposes.

#### Estimates of Cost

Estimates of capital and annual costs for importation and distribution of Colorado River water in Ventura County are presented in this section. The estimates, while preliminary in nature, include all anticipated expenses in connection with construction and operation of the facilities considered. Scope of the studies, however, was limited to facilities for delivery of the supplemental water supply to a strategic location in each of the four hydrologic units, and the estimates do not include costs of final distribution of water to individual users. However, the system described in connection with plans for local conservation development could be utilized for distributing Colorado River water in the Oxnard Plain Subunit. The estimates do not include costs for any required treatment of the portion of the water that would be used for domestic or municipal uses.

Capital costs for the Ventura County Aqueduct, terminal reservoirs, and distribution system were estimated from quantities determined from preliminary designs, and from unit prices of construction items taken from recent bid data for projects similar to those in question or from manufacturers' cost lists. Allowance was made in the estimates for acquisition of necessary lands, easements, and rights of way. It was assumed that easements would be obtained gratis within existing public right of way. It was estimated that construction of the aqueduct would require four years, and interest on the capital cost of construction items at a rate of 4 per cent over one-half of this construction period, was included in the cost estimates. Allowances in the amount of 10 per cent of construction costs for engineering and administration, and 15 per cent for contingencies were also included. In addition, officials of the Metropolitan Water District estimated that were a conduit with capacity of 100 second-feet to be constructed for Ventura County, an additional cost of \$2,000,000 would be required for enlargement of the proposed Lower Orange County Feeder from Lake Matthews to the Walnut Canyon take-off to accommodate the required increased capacity. Allowances in the costs estimates for increasing the size of the Lower Orange County Feeder for capacities of the Ventura County Aqueduct other than the foregoing 100 second-feet were taken as proportional to the ratio of capacities.

The Metropolitan Water District of Southern California currently charges \$10 per acre-foot for untreated Colorado River water. Public agencies annexing to the District are also required to pay their share of the capital costs of the Metropolitan Water District system. Annual payments beginning in the fiscal year 1929-30 are assessed for this purpose, based upon the assessed valuation of the area seeking admission. Four per cent simple interest is charged on these back taxes, and the total amount due may be paid by annual amortization payments on a 4 per cent interest basis over a 30-year period. In

addition to back payments, current taxes must be paid annually. For purposes of cost analysis, it was assumed that Ventura County would annex to the Metropolitan Water District during the fiscal year 1953-54, and that the first taxes would be assessed during the fiscal year 1954-55. From the current rate of increase in assessed valuation of the County, it was estimated that the assessed valuation therein would be \$306,000,000 in the fiscal year 1953-54, and \$329,000,000 in the fiscal year 1954-55. It was also assumed that the tax rate of the Metropolitan Water District for 1953-54, of 0.25 per \$100 of assessed valuation, would prevail in 1954-55. Based on these assumptions, it was estimated that back taxes, together with interest, payable by Ventura County would be about \$15,570,000, which, if amortized over the 30-year period at 4 per cent, would result in annual payments of about \$900,000. This includes the tax payment during the first year which would be about \$822,000. Presented in Table 107 is a yearly summary of back taxes and interest that would be payable by Ventura County to the Metropolitan Water District of Southern California, if annexation were made during the fiscal year 1953-54.



TABLE 107

ESTIMATED BACK TAXES AND INTEREST PAYABLE  
BY VENTURA COUNTY IF ANNEXED TO  
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA  
BETWEEN DECEMBER 1, 1953 AND DECEMBER 1, 1954

		: Tax rate	:	:	:	:
		: levied	:	:	:	:
		: per \$100	:	:	:	:
Fiscal year	Assessed valuation	: by Metro- politan Water District	: Interest rate	: Tax	: Interest at 4 per cent	: Total payment
1929-30	\$106,619,530	\$.04	.9994301	\$ 42,650	\$ 42,630	\$ 85,280
1930-31	108,330,350	.03	.9594301	32,500	31,180	63,680
1931-32	107,906,370	.03	.9194301	32,370	29,760	62,130
1932-33	83,367,180	.04	.8794301	33,350	29,330	62,680
1933-34	76,817,450	.04	.8394301	30,730	25,800	56,530
1934-35	76,618,310	.10	.7994301	76,620	61,250	137,870
1935-36	82,715,200	.20	.7594301	165,430	125,630	291,060
1936-37	85,450,010	.37	.7194301	316,170	227,460	543,630
1937-38	96,930,330	.40	.6794301	387,720	263,430	651,150
1938-39	94,096,290	.40	.6394301	376,390	240,680	617,070
1939-40	96,512,720	.42	.5994301	405,350	242,980	648,330
1940-41	98,324,780	.49	.5594301	481,790	269,530	751,320
1941-42	100,452,480	.48	.5194301	482,170	250,450	732,620
1942-43	104,977,410	.48	.4794301	503,890	241,580	745,470
1943-44	111,066,070	.48	.4394301	533,120	234,270	767,390
1944-45	123,654,720	.48	.3994301	593,540	237,080	830,620
1945-46	135,536,120	.50	.3594301	677,680	243,580	921,260
1946-47	144,515,160	.48	.3194301	693,670	221,580	915,250
1947-48	160,209,280	.35	.2794301	560,730	156,680	717,410
1948-49	189,539,050	.34	.2394301	644,430	154,300	798,730
1949-50	228,724,090	.34	.1994301	777,660	155,090	932,750
1950-51	241,826,230	.31	.1594301	749,660	119,520	869,180
1951-52	257,003,000	.30	.1194301	771,010	92,080	863,090
1952-53	283,230,490	.29	.0794301	821,370	65,240	886,610
1953-54	306,000,000*	.25	.0394301	765,000	30,160	795,160
1954-55	329,000,000*	.25*	.0018411	822,500	1,510	824,010
TOTALS				\$11,777,500	\$3,792,780	\$15,570,280

Annual amortization payment,  
30 years, 4 per cent interest

\$900,400

\* Estimated

Estimates of annual costs also included interest on and amortization of the capital investment, and electrical power charges for pumping. The charges for electrical energy were in accordance with schedual PAP-2 of the Southern California Edison Company, which was effective on September 1, 1946.

Presented in Table 108 is a summary of the estimated costs of the proposed Ventura County Aqueduct with five alternative discharge capacities. Costs shown in Table 108 do not include costs of distributing Colorado River water from the terminal reservoirs to strategic points within the county. Such costs are only estimated for a Ventura County Aqueduct with discharge capacity of 150 second-feet. Estimates of initial capital and annual distribution costs for this size of aqueduct are summarized in Table 109.

TABLE 108

SUMMARY OF ESTIMATED COSTS OF VENTURA COUNTY AQUEDUCT  
TO CONNECT WITH SYSTEM OF METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Item	Capacity of aqueduct, in second feet, and delivered water supply, in acre-feet per season			
	25	50	75	100
	18,000	36,000	54,000	72,000
				150
				108,000
<b>CAPITAL COSTS</b>				
Proportionate cost of Lower				
Orange County Feeder	\$ 500,000	\$ 1,000,000	\$ 1,500,000	\$ 2,000,000
Ventura County Aqueduct	16,427,000	26,614,000	30,912,000	35,611,000
Oak Canyon Lateral	---	---	200,000	200,000
Conejo Regulating Reservoir	2,966,000	2,966,000	2,966,000	2,966,000
Oak Canyon Regulating Reservoir	---	---	1,460,000	1,460,000
TOTALS	\$19,893,000	\$30,580,000	\$37,038,000	\$42,237,000
				\$53,996,000
<b>ANNUAL COSTS</b>				
Payments to Metropolitan Water District				
Cost of water	\$ 180,000	\$ 360,000	\$ 540,000	\$ 720,000
Back taxes and interest	900,000	900,000	900,000	900,000
Current taxes	823,000	823,000	823,000	823,000
Interest on capital investment	796,000	1,223,000	1,482,000	1,690,000
Amortization of capital investment	209,000	322,000	390,000	444,000
Energy charges	114,000	225,000	375,000	463,000
Operation and maintenance	50,000	77,000	93,000	106,000
TOTALS	\$3,072,000	\$3,930,000	\$4,603,000	\$5,146,000
				\$6,276,000
<b>AVERAGE ANNUAL</b>				
COST OF WATER DELIVERED TO VENTURA COUNTY, PER ACRE-FOOT	171	109	85	71
				58



TABLE 109

SUMMARY OF ESTIMATED INITIAL COSTS OF DISTRIBUTING COLORADO RIVER WATER  
 WITHIN VENTURA COUNTY, WITH VENTURA COUNTY AQUEDUCT  
 OF 150 SECOND-FOOT CAPACITY

Item	Estimated Costs	
	Capital	Annual
Calleguas-Conejo Distribution System	\$ 4,800,000	\$ 257,000
Oxnard- City of Ventura Conduit	5,868,000	311,000
Oxnard Plain-Pleasant Valley Distribution System	3,038,000	169,000
TOTALS	\$ 13,706,000	\$ 737,000

## Discussion of Alternative Initial Plans for Water Supply Development

Presented in this section is a discussion of possible alternative initial plans for water supply development in Ventura County, as related to their accomplishments, and to their feasibility for immediate construction, financing, and operation by local interests. It has been shown that immediate sources of supplemental water include local conservation developments, both surface and underground, and the Colorado River through facilities of the Metropolitan Water District of Southern California.

In the future, a water supply sufficient to satisfy the portion of forecast ultimate requirements in excess of the probable maximum supply that could be developed locally in the County, will be available from the Feather River Project. Supplemental water available from this project should not be considered as competitive or substitutional to either potential local conservation developments or to the imported supply that might be obtained from the Metropolitan Water District. The cost of supplemental water from the Feather River Project, which on the basis of preliminary designs and financial analyses was estimated in 1951 to be \$50 an acre-foot delivered to southern California, might be used as a guide in establishing the limit to which water resources of Ventura County should be developed. However, this should not be taken as a rigid criterion for limiting local development. Provision for a supplemental water supply for Ventura County is a matter of immediate concern, whereas the timing of financing and constructing the Feather River Project is as yet undetermined.

The selection of an initial plan of water resources development for Ventura County and of the component features thereof was based on consideration of the following factors: (1) Present and forecast future supplemental water requirements of the County; (2) the amount of new water that would be developed under a given plan or feature thereof, relative to that under alternative plans;

3) the capital cost of a given plan relative to that of alternative plans; (4) the annual cost of net safe yield that would be developed under a given plan relative to that under alternative plans; (5) the annual cost of incremental net safe yield that would be developed from various sizes of a given plan or component feature thereof; and (6) the limit of bonding capacity of the County for water resources development.

In regard to the latter factor, it has been estimated that the present bonding capacity of Ventura County for financing water resources development does not exceed \$50,000,000. From a practical standpoint, it may be that bonds in this amount could not be marketed at reasonable interest rates. This latter consideration is therefore an important factor in selecting an initial plan for the development of the water resources of the County.

There is presented in Appendix D a discussion of organizational and financial aspects attendant upon plans for providing supplemental water for Ventura County. As described in this appendix, it appears that under the existing political structure in the County, the Ventura Hydrologic Unit is the only unit with the financial capacity to develop supplemental water in an amount sufficient to satisfy its present water supply deficiency. It is believed that only through the formation of a single county-wide water agency, organized with appropriate powers, can a sound comprehensive program of water resources development be financed. It is considered that such an agency is necessary not only to undertake the development of local water resources, but also to obtain imported water from either the Colorado River Aqueduct or the Feather River Project.

Were such a county-wide water district to be formed in Ventura County, its function would be to finance, construct, and operate major projects, and to execute water service contracts with subordinate districts. The existing Ventura Municipal Water District, and United Water Conservation District, with



possible modification of the powers of the latter agency, could convey and distribute water within their respective areas. A similar district would necessarily have to be formed in the Calleguas-Conejo and Malibu Hydrologic Units. In some areas of the County, distribution of water to individual users might be undertaken by improvement districts which would be formed for this purpose.

A direct benefit would inure to all of Ventura County through the formation of a county-wide water district, as a result of broadening of the tax base of the constructing agency, and corresponding enhancement of the financial capacity thereof. With a broader tax base, it would appear that more favorable interest rates could be obtained on bond issues for water resources development. Furthermore, increased flexibility in utilization of developed water supplies would be possible as the needs of the various hydrologic units demanded. In the Ventura Hydrologic Unit, it is indicated that supplemental water in excess of the immediate requirements could feasibly be developed. From an engineering standpoint, it has been demonstrated that it would be possible to divert a portion of this surplus for interim use in the Oxnard Plain Subunit. With construction of a reservoir at the Casitas site by a county-wide agency, this surplus could be temporarily contracted and sold to users in the water deficient coastal plain of the Santa Clara River Valley, thereby relieving tax payers of the Ventura Hydrologic Unit of the burden of paying for water not presently needed.

It has been demonstrated that costs of water available to Ventura County through the construction of potential surface storage developments, or by importation through facilities of the Metropolitan Water District of Southern California are quite expensive, both in capital cost of construction of required works and in unit cost of water made available. It has also been shown that the least expensive source of supplemental water available to Ventura County is extant in presently undeveloped ground water storage, but that development

f this source is limited by possible interference with the rights of overlying ground water users.

Surface storage developments considered varied in capital cost from about \$4,000,000 to \$44,000,000, with developed net safe yields varying from a minimum of about 2,500 acre-feet per season to about 27,000 acre-feet per season. Average annual unit cost of net safe yield varied from a minimum of about \$30 per acre-foot to in excess of \$150 per acre-foot at the reservoir. The more feasible of the developments studied would vary in capital cost from about \$8,000,000 to about \$15,000,000, with net safe yields varying from about 12,000 to 22,000 acre-feet per season. Average annual unit cost of net safe yield that could be made available by construction of the more favorable developments ranged from \$30 to \$50 per acre-foot.

For comparative purposes, there is presented in Table 110 a recapitulation of yields of water that would be developed by construction of the several storage capacities considered at each of the ten dam and reservoir sites studied in Ventura County. Presented in Table 111 is an economic comparison of potential Ventura County reservoirs. The estimated costs are based on an assumed 4 per cent interest rate. The estimates do not include costs of distribution facilities, and the unit costs of new water shown are indicative of such costs at the reservoirs. Certain of the relationships shown in Table 111 are depicted graphically on Plates 35, 36, and 37.

TABLE 110

\*with 80 second-foot capacity Piru-Las Posas Diversion. Indicated yields include average seasonal export of 20,100 acre-feet to



## ECONOMIC COMPARISON OF POTENTIAL VENTURA COUNTY RESERVOIRS

Reservoir	Storage capacity,		Net safe <sup>a</sup> seasonal yield,	Capital cost		Average annual cost	
	Gross	Net		Total	Per acre-foot of gross storage capacity	Total	Per acre-foot of net safe yield
Coyote Creek Casitas (with 200 second- foot diversion)	92,000 105,000 130,000 156,000	90,000 103,000 128,000 154,000	14,000 15,600 18,600 21,900	\$10,049,500 10,789,600 12,875,200 20,748,000	\$109 103 99 133	\$ 526,700 567,100 675,500 1,077,300	\$ 38 36 36 49
							\$ 25 36 121
Santa Paula Creek Ferndale	12,000 24,000 34,000	10,000 22,000 32,000	2,500 4,900 6,600	5,374,000 7,248,500 9,864,600	448 302 290	276,500 372,700 505,400	111 76 77
							40 62 22 45
Sespe Creek Cold Spring	35,000 43,000 77,000 100,000	32,000 40,000 74,000 97,000	5,000 6,500 10,500 12,000	3,796,100 5,612,800 7,282,700 8,571,000	108 131 95 86	199,200 291,500 377,900 445,500	40 45 36 37
							60 53 49
Topatopa	50,000 75,000 100,000	42,000 67,000 92,000	8,000 12,400 16,500	9,155,000 12,521,000 15,544,000	183 167 155	482,500 652,500 805,300	60 53 49
							107
Hammel	25,000 50,000	13,000 38,000	4,000 9,500	12,887,500 24,490,900	516 490	666,100 1,252,200	166 132
							77 72 84
Fillmore	64,000 98,000 148,000	52,000 86,000 136,000	12,500 20,000 27,000	18,966,400 28,352,200 44,679,600	296 289 302	968,200 1,444,900 2,272,700	77 72 84
							64 118
Piru Creek Upper Blue Point	50,000	38,000	6,500	8,529,800	171	438,400	67
Blue Point	50,000	38,000	6,500	8,170,900	163	420,300	65
Devil Canyon	100,000 150,000 150,000 <sup>b</sup>	87,000 137,000 137,000	15,000 22,000 33,400	12,118,700 15,486,500 15,486,500	121 103 103	624,700 798,100 798,100	42 36 24
							25
Santa Felicia	50,000 75,000 100,000	36,000 61,000 86,000	6,600 11,000 15,000	7,127,500 8,417,300 9,028,700	143 112 90	369,100 435,200 468,600	56 40 31
							15 8

<sup>a</sup>Yields of reservoirs on tributaries of Santa Clara River are from uniform release method of operation, with releases for maintenance of ground water levels.

<sup>b</sup>With 80 second-foot diversion to Calleguas-Conejo Hydrologic Unit.

As shown on Table 110, for reservoirs on tributaries of the Santa Clara River, new water that would be made available to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits, if the reservoirs were operated under the uniform release method and the water was conveyed to the three subunits by surface conduit, would substantially exceed new water made available thereto under the rapid release method of operation. Therefore, further consideration was not given the rapid release method of operation, and all yields of water hereinafter referred to in connection with these reservoirs are those that would result with uniform release operation.

Presented previously in this chapter was a discussion of possible annexation of Ventura County to the Metropolitan Water District of Southern California, together with estimates of cost of constructing various capacities of aqueduct to connect with the Metropolitan Water District system, and annual costs that would result from such annexation and construction. It was shown that for the capacities of aqueduct considered, capital costs, including the costs of terminal regulation in Ventura County, varied from about \$20,000,000 to about \$54,000,000. The average annual unit cost of water delivered to Ventura County varied from about \$170 per acre-foot for the smallest capacity aqueduct, to about \$58 per acre-foot for the largest capacity considered. These costs may be compared with values presented in Table 111. It may be noted that for the four more favorable local reservoirs in Ventura County, average annual costs per acre-foot of net safe yield are substantially less than similar costs of Colorado River water delivered to Ventura County, for all capacities of aqueduct considered. Although the unit cost of delivered Colorado River water shows a marked decrease with increase in aqueduct capacity, there is also a substantial increase in required capital expenditure.

It is believed that if Ventura County were to annex to the Metropolitan Water District of Southern California, sufficient aqueduct capacity should

be constructed initially to eliminate present water resources problems and to provide for future growth of the County. This follows from the fact that the aqueduct does not appear to be susceptible to staged development. To achieve this objective, an aqueduct with capacity of at least 150 second-feet should be constructed. The indicated capital cost of constructing such an aqueduct is about \$54,000,000. Aqueducts of lesser capacity would provide insufficient supplemental water at a relatively high capital outlay. Also, as stated, the average annual unit cost of water so delivered does not compare favorably with that of potential local conservation developments.

From examination of Tables 110 and 111, and of Plates 35, 36, and 37, it is indicated that of the potential surface storage developments studied in Ventura County, the Casitas site on Coyote Creek, the Cold Spring and Topatopa sites on Sespe Creek, and the Devil Canyon and Santa Felicia sites on Piru Creek are the most favorable from the standpoint of capital cost, amount of net safe yield developed, and average annual unit cost per acre-foot of net safe yield. The remainder of the sites considered, although favorable in some respects, and possibly worthy of consideration in the future, were not given further consideration for initial development.

Of the four sizes of reservoir considered at the Casitas site, it may be noted that a definite increase in yield persists as reservoir capacity is enlarged, but that the average annual unit cost of the 21,900 acre-feet of net safe yield that would be developed by the 156,000 acre-foot reservoir would be about \$49 per acre-foot, or substantially in excess of the comparable costs of yield developed by the smaller sizes of reservoir. Furthermore, the average annual



cost per acre-foot of incremental yield between the 130,000 and 156,000 acre-foot reservoirs was estimated to be about \$121 per acre-foot. Between the reservoirs of 105,000 and 130,000 acre-foot storage capacity the estimated average annual unit cost of incremental yield was only \$36 per acre-foot. For these reasons, it was concluded that the most desirable capacity of reservoir at the Casitas site would be about 130,000 acre-feet.

Estimates of cost of yield for various capacities of Cold Spring Reservoir indicate that this site is suitable for the construction of a dam and reservoir with a storage capacity of 100,000 acre-feet, and that the site is the most favorable of those studied on Sespe Creek. A reservoir of this capacity at the Cold Spring site would be the least expensive to construct, and have the lowest annual cost per acre-foot of net safe yield developed. As was stated in earlier discussion of this reservoir, there are uncertainties regarding runoff at the dam site. Based on available hydrographic data, and upon rough estimates of runoff for the period from 1894-95 through 1950-51, an analysis was made of the probable time required to fill Cold Spring Reservoir after its construction. It was estimated that for the 100,000 acre-foot reservoir, about 16 years on the average would have been required for the reservoir to fill after construction. Thus, it is indicated, on the basis of the sparse hydrographic data available, that 100,000 acre-feet of storage capacity at the Cold Spring site probably approaches the absolute maximum which should be constructed. In order to protect the site against either underdevelopment or construction of excess capacity, it was concluded that construction of a Cold Spring Reservoir should be postponed until such time as adequate hydrographic data become available.

Analysis was made of the Topatopa, Santa Felicia, and Devil Canyon sites, which as stated appear to be favorable for initial construction, to ascertain the most feasible storage capacity at each of the sites under a plan of coordinated operation. In this connection, it should be emphasized that construction of a reservoir at the Santa Felicia site would preclude subsequent construction of a reservoir at the Devil Canyon site. Conversely, if a reservoir

were to be constructed at the Devil Canyon site this would eliminate the possibility of building a dam at the Santa Felicia site. In Table 111 it is shown that for a reservoir storage capacity of 100,000 acre-feet, the Santa Felicia site is more favorable than the Devil Canyon site from the standpoints of both capital cost and annual cost per acre-foot of net safe yield, and that in these respects it is also more favorable than a comparable capacity at the Topatopa site on Sespe Creek. As has been stated, construction of reservoir capacity at the Santa Felicia site is limited to a maximum of about 100,000 acre-feet, while at the Devil Canyon site a dam creating storage capacities up to about 150,000 acre-feet is considered feasible. The Topatopa site also is considered limited to a maximum storage capacity of about 100,000 acre-feet.

There is presented in Table 112 an economic comparison of selected combinations of reservoir storage capacities at the Santa Felicia, Topatopa, and Devil Canyon sites. The estimated costs are based on an assumed 4 per cent interest rate. It may be noted that this analysis was made under the assumption that the reservoirs would be operated coordinately under the uniform release method. Values are presented showing the accomplishments of various combinations of reservoir storage capacity at the three sites, operated both with releases for maintenance of ground water levels and without such releases. It will be noted that for any given combination of reservoir capacity, not only would the greatest yields be obtained without releases for maintenance of ground water levels, but also the average annual cost per acre-foot of net safe yield would be substantially less without such releases. It is also shown in Table 112 that the largest yields of water with the lowest annual unit costs are obtained with a Devil Canyon Reservoir of storage capacity of 150,000 acre-feet operated for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units.

TABLE 112

ECONOMIC COMPARISON OF SELECTED COMBINATIONS OF POTENTIAL RESERVOIRS  
ON SESPE AND PIRU CREEKS, WITH UNIFORM RELEASE OPERATION

Gross reservoir storage capacity, in acre-feet			Net safe seasonal yield, in acre-feet			Capital costs			Average annual costs		
:	:	:	:	:	:	:	:	:	:	:	:
Santa :	Devil :	Topatopa :	releases for :	With :	Without :	Per acre- :	With :	Without :	Per acre-foot :	With :	Without :
Felicia :	Devil :	Topatopa :	releases for :	With :	Without :	foot of :	releases for :	Without :	of yield :	releases :	Without :
:	:	:	maintenence :	maintenence :	maintenence :	gross :	maintenence :	maintenence :	Total :	maintenence :	maintenence :
:	:	:	of ground :	of ground :	of ground :	storage :	of ground :	of ground :	of ground :	of ground :	of ground :
:	:	:	water levels :	water levels :	water levels :	capacity :	water levels :	water levels :	water levels :	water levels :	water levels :
100,000	100,000	200,000	35,000	30,500	\$24,572,700	\$123	\$	806	\$ 702	\$ 1,273,900	\$ 36
100,000	75,000	175,000	31,000	26,500	21,549,700	123	813	813	695	1,121,100	36
100,000	50,000	150,000	27,400	23,000	18,183,700	121	791	791	664	951,100	35
75,000	100,000	175,000	30,800	27,000	23,961,300	137	887	887	778	1,240,500	40
75,000	75,000	150,000	26,800	23,000	20,938,300	140	910	910	781	1,087,700	41
75,000	50,000	125,000	22,300	19,000	17,572,300	141	925	925	788	917,700	41
50,000	100,000	150,000	26,400	23,000	22,671,500	151	986	986	859	1,174,400	44
50,000	75,000	125,000	22,300	18,900	19,648,500	157	1,040	1,040	881	1,021,600	46
50,000	50,000	100,000	17,900	14,600	16,282,500	163	1,115	1,115	910	851,600	48
100,000	150,000	250,000	42,500	37,500	31,030,500	124	827	827	730	1,603,400	38
100,000	150,000*	250,000	54,100	48,900	31,030,500	124	635	635	574	1,603,400	30
75,000	150,000	225,000	39,500	34,000	28,007,500	124	824	824	709	1,450,600	37
50,000	150,000	200,000	36,000	31,000	24,641,500	123	795	795	684	1,280,600	36
100,000	100,000	200,000	35,000	30,500	27,662,700	138	907	907	790	1,430,000	41
75,000	100,000	175,000	31,500	26,500	24,639,700	141	930	930	782	1,277,200	41
50,000	100,000	150,000	27,500	23,000	21,273,700	142	925	925	774	1,107,200	40

\*With 80 second-foot capacity Piru-Las Posas Diversion. Indicated yields include an average seasonal export of 20,100 acre-feet to Calleguas-Conejo Hydrologic unit during base period.



It is shown in Table 112 that under the indicated plans of coordinated operation for the sole benefit of the Santa Clara River Hydrologic Unit, slightly lower unit costs of developed yield would be obtained with either Devil Canyon or Santa Felicia Reservoirs constructed to the indicated maximum capacity, and with Topatopa Reservoir constructed to a capacity of 50,000 acre-feet. However, there would be but a slight increase in unit cost of net safe yield with maximum storage capacity at Topatopa and with maximum storage capacity at either Santa Felicia or Devil Canyon. Because of the general paucity of feasible dam sites in Ventura County, it is believed that the more favorable sites should be developed to the maximum practicable capacity in consonance with engineering and economic criteria. It was concluded, therefore, that any dam constructed at the Topatopa site should provide a reservoir storage capacity of about 100,000 acre-feet, and that storage capacity constructed at the Santa Felicia or Devil Canyon sites should not be less than about 100,000 or 150,000 acre-feet, respectively, depending upon the site developed.

There follows a discussion of three alternative basic plans considered feasible for initial construction and operation by an appropriate county-wide water agency in Ventura County. There are also presented three additional plans, that would achieve similar accomplishments in terms of water yield, but at a lesser cost through planned operation of ground water storage in the Santa Clara River Hydrologic Unit. The estimated costs of new water cited are based on an assumed 4 per cent interest rate.

#### Plan I

Under the provisions of this plan relating to the Ventura Hydrologic Unit, Casitas Reservoir would be constructed to a storage capacity of 130,000 acre-feet, together with a distribution system to serve each subunit. The capacity of the distribution system would be about 13,400 acre-feet per season. It was assumed that a seasonal supply of 1,400 acre-feet would be delivered to

the Ojai Subunit from Matilija Reservoir through the existing line.

Under Plan I in the Santa Clara River Hydrologic Unit, both Santa Felicia and Topatopa Reservoirs would be constructed, each with a storage capacity of 100,000 acre-feet. The Santa Clara River Conduit would be constructed, and would have a capacity at its terminus at Oxnard Reservoir of 120 second-feet. A distribution system to supply about 30,000 acre-feet of agricultural water per season and about 10,000 acre-feet of municipal water per season to the Oxnard Plain and Pleasant Valley Subunits would be included in the plan. The Casitas-Oxnard Plain Diversion Conduit would be constructed with a capacity of 25 second-feet, and would deliver a seasonal supply of about 10,000 acre-feet to Oxnard Reservoir.

Under Plan I, initially about 8,600 acre-feet per season of supplemental water would be made available at strategic points in the Ventura Hydrologic Unit, at an estimated average annual cost of \$62 per acre-foot. About 40,000 acre-feet of supplemental water per season would be delivered to users in the Oxnard Plain and Pleasant Valley Subunits, at an estimated average annual unit cost of \$58 per acre-foot. The total net safe seasonal yield developed by features of the plan would be about 49,000 acre-feet, with an estimated average annual unit cost of \$58 per acre-foot delivered to users in the Oxnard Plain and Pleasant Valley Subunits and to strategic points in the Ventura Hydrologic Unit. The estimated capital cost of Plan I would be about \$52,000,000.

#### Plan IA

Plan IA would include the same component features as Plan I, except that in lieu of 100,000 acre-feet of reservoir storage capacity at the Topatopa site, a well field would be constructed in Fillmore Basin and operated to yield an average supply of new water to the Oxnard Forebay Subunit of about 16,000 acre-feet per season. In addition, Santa Felicia Reservoir would be operated

on the uniform release basis without effecting releases to maintain historic ground water levels in Piru, Fillmore, and Santa Paula Basins. Under provisions of this plan, an average seasonal supplemental supply of about 45,000 acre-feet of water would be delivered to Oxnard Reservoir from developments in the Santa Clara River watershed and from Casitas Reservoir. The estimated capital cost of Plan IA would be about \$36,000,000. The estimated average annual unit cost of new water delivered to users in the Oxnard Plain and Pleasant Valley Subunits would be \$34 per acre-foot. The total seasonal yield of new water developed by features of the plan would be about 54,000 acre-feet. The estimated average annual unit cost of net safe yield so developed would be about \$39 per acre-foot.

## Plan II

Component features of Plan II would be the same as Plan I, except that in lieu of 100,000 acre-feet of reservoir storage capacity at the Santa Felicia site, Devil Canyon Reservoir would be constructed to a storage capacity of 150,000 acre-feet, and would be operated for the benefit of the Santa Clara River Hydrologic Unit alone, under the uniform release method of operation and with releases to maintain historic ground water levels in Piru, Fillmore, and Santa Paula Basins. The yield of new water in the Ventura Hydrologic Unit and the average annual unit cost thereof would be the same as in the preceding alternative plans. In the Santa Clara River Hydrologic Unit, about 47,500 acre-feet per season of new water would be made available in the Oxnard Plain and Pleasant Valley Subunits, at an estimated average annual unit cost of \$56 per acre-foot. The total new water supply that would be developed under the provisions of Plan II would be about 56,000 acre-feet per season, having an estimated average annual unit cost of \$57 per acre-foot. The estimated capital cost of Plan II would be about \$59,000,000.



### Plan IIA

Plan IIA includes the same features as Plan II, except that in lieu of a 100,000 acre-foot reservoir at the Topatopa site, new water in the amount of about 16,000 acre-feet per season would be extracted from the well field in Fillmore Basin, and conveyed to the Oxnard Plain and Pleasant Valley Subunits for use therein. In the Ventura Hydrologic Unit the amount of new water developed, and the average annual unit cost thereof would be the same as in the preceding alternative. In the Santa Clara River Hydrologic Unit, about 53,000 acre-feet per season of new water would be made available to the Oxnard Plain and Pleasant Valley Subunits, at an estimated average annual unit cost of \$35 per acre-foot. The total new water supply developed by Plan IIA would be about 62,000 acre-feet per season, at an estimated average annual unit cost of \$39 per acre-foot. The estimated capital cost of Plan IIA would be about \$43,000,000.

### Plan III

Plan III includes the same component features as Plan II, except that Devil Canyon Reservoir would be operated for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units, and the Piru-Las Posas Conduit would be constructed with a capacity of 80 second-feet and would deliver water from Devil Canyon Reservoir to the Happy Camp Canyon and Dry Canyon spreading grounds in the East Las Posas and Simi Subunits, respectively. Releases from Devil Canyon and Topatopa Reservoirs to the Santa Clara River Conduit would be under the uniform release method of operation, with releases for maintenance of historical ground water levels in Piru, Fillmore, and Santa Paula Basins.

Under the provisions of Plan III, the amount of new water and the average unit cost thereof in the Ventura Hydrologic Unit would be the same as in the preceding alternative. About 39,000 acre-feet per season of new water would be developed for use in the Oxnard Plain and Pleasant Valley Subunits, at an estimated average annual unit cost of \$56 per acre-foot. Similarly, an average

seasonal new water supply of about 20,000 acre-feet would be delivered to the Calleguas-Conejo Hydrologic Unit at the foregoing spreading grounds, at an estimated average annual unit cost of \$48 per acre-foot. The total new water supply developed under the provisions of Plan III would be about 67,000 acre-feet per season, at an estimated average annual unit cost of \$54 per acre-foot. The estimated capital cost of Plan III would be about \$68,000,000.

#### Plan IIIA

The features of Plan IIIA would be the same as those in Plan III, except that in lieu of a 100,000 acre-feet reservoir at the Topatopa site, new water in the amount of about 16,000 acre-feet per season would be extracted from the well field in Fillmore Basin and conveyed to the Oxnard Plain and Pleasant Valley Subunits, for use therein. In addition, Devil Canyon Reservoir would be operated under the uniform release method, without releases to maintain historic ground water levels in Piru, Fillmore, and Santa Paula Basins.

In the Ventura Hydrologic Unit, the amount of new water and average annual unit cost thereof would be the same as in the preceding alternative. A new water supply of about 44,000 acre-feet per season would be delivered for use in the Oxnard Plain and Pleasant Valley Subunits, at an estimated average annual unit cost of \$33 per acre-foot. As under provisions of Plan III, about 20,000 acre-feet of new water per season would be delivered to the Happy Camp Canyon and Dry Canyon spreading grounds in the Calleguas-Conejo Hydrologic Unit, at an estimated annual unit cost of \$45 per acre-foot. The total new water supply that would be developed under the provisions of Plan IIIA would be about 73,000 acre-feet per season, at an estimated average annual unit cost of about \$40 per acre-foot. The estimated capital cost of Plan IIIA would be about \$52,000,000.

#### Comparison of Alternative Plans

There is presented in Table 113 a summary comparison of estimated costs

and yields of water that would result under alternative Plans I, II, and III. Presented in Table 114 is a summary comparison of cost and yields of water that would result under the provision of Plan IA, IIA, and IIIA. It is apparent from examination of these tables that with planned operation of ground water storage both capital and annual costs of plans with similar accomplishments in water yield would be substantially reduced.

Because of uncertainties regarding interest rates that could be obtained in financing of the foregoing alternative plans, there is presented in Table 115 a comparison of costs that would result with interest rates of 3 per cent, 4 per cent, and 5 per cent.



TABLE 1113

ESTIMATED COSTS AND YIELDS OF WATER OF ALTERNATIVE INITIAL PLANS  
FOR WATER SUPPLY DEVELOPMENT, WITHOUT PLANNED OPERATION  
OF GROUND WATER STORAGE IN SANTA CLARA RIVER HYDROLOGIC UNIT

Item	Plan I					Plan II					Plan III				
	Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :		Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :		Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :	
Ventura Hydrologic Unit															
Casitas Reservoir <sup>a</sup>	\$12,875,200	8,600	\$ 312,300	--		\$12,875,200	8,600	\$ 312,300	--		\$12,875,200	8,600	\$ 312,300	--	
Distribution System <sup>b</sup>	2,953,800	---	223,800	--		2,953,800	---	223,800	--		2,953,800	---	223,800	--	
Subtotals	\$15,829,000	8,600	\$ 536,100	\$62		\$15,829,000	8,600	\$ 536,100	\$62		\$15,829,000	8,600	\$ 536,100	\$62	
Santa Clara River Hydrologic Unit															
Casitas Reservoir <sup>a</sup>	\$ ---	10,000	\$ 363,200	--		\$ ---	10,000	\$ 363,200	--		\$ ---	10,000	\$ 363,200	--	
Casitas-Oxnard Plain															
Diversion Conduit	1,670,500	---	127,100	--		1,670,500	---	127,100	--		1,670,500	---	127,100	--	
Santa Felicia Reservoir	9,028,700	30,500	(468,600)	--											
Topatopa Reservoir	15,544,000	---	(805,300)	--		15,544,000	---	(805,300)	--		15,544,000	---	(805,300)	--	
Devil Canyon Reservoir <sup>a</sup>	---	---	---	--		15,486,500	---	(798,100)	--		6,166,800	---	(317,900)	--	
Santa Clara River Conduit	5,658,900	---	302,300	--		5,763,500	---	307,800	--		5,763,500	---	307,800	--	
Fillmore Well Field	---	---	---	--		---	---	---	--		---	---	---	--	
Municipal Distribution System	1,317,500	---	94,300	--		1,317,500	---	94,300	--		1,317,500	---	94,300	--	
Agricultural Distribution System	3,037,700	---	168,700	--		3,037,700	---	168,700	--		3,037,700	---	168,700	--	
Subtotals	\$36,257,300	40,500	\$2,329,500	\$58		\$42,819,700	47,500	\$2,664,500	\$56		\$33,500,000	38,800	\$2,184,300	\$56	
Calleguas-Conejo Hydrologic Unit															
Devil Canyon Reservoir <sup>a</sup>	---	---	---	--		---	---	---	--		\$ 9,319,700	20,100	\$ 480,200	--	
Piru-Las Posas Diversion Conduit	---	---	---	--		---	---	---	--		6,960,500	---	369,000	--	
Spreading works in East Las	---	---	---	--		---	---	---	--		---	---	---	--	
Pumas and Simi Basins	---	---	---	--		---	---	---	--		2,014,200	---	106,800	--	
Subtotals	---	---	---	--		---	---	---	--		\$18,294,400	20,100	\$ 956,000	\$48	
TOTALS	\$52,086,300	49,100	\$2,865,600	\$58		\$58,648,700	56,100	\$3,200,600	\$57		\$67,623,400	67,500	\$3,676,400	\$54	

<sup>a</sup>Average annual cost proportioned on basis of yields.<sup>b</sup>Energy charges presented in Appendix C reduced by \$28,200 because of lesser initial delivery.

TABLE 114

**ESTIMATED COSTS AND YIELDS OF WATER OF ALTERNATIVE INITIAL PLANS  
FOR LATER SUPPLY DEVELOPMENT, WITH PLANNED OPERATION  
OF GROUND WATER STORAGE IN SANTA CLARA RIVER HYDROLOGIC UNIT**

Item	Plan IA				Plan IIA				Plan IIIA			
	Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :	Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :	Capital cost	Net safe : seasonal : yield, in : acre-feet :	Average : annual cost :	Per : acre : foot : of : yield :
Ventura Hydrologic Unit												
Casitas Reservoir <sup>a</sup>	\$12,875,200	8,600	\$ 312,300	--	\$12,875,200	8,600	\$ 312,300	--	\$12,875,200	8,600	\$ 312,300	--
Distribution System <sup>b</sup>	<u>2,953,800</u>	---	<u>223,800</u>	--	<u>2,953,800</u>	---	<u>223,800</u>	--	<u>2,953,800</u>	---	<u>223,800</u>	--
Subtotals	\$15,829,000	8,600	\$ 536,100	\$62	\$15,829,000	8,600	\$ 536,100	\$62	\$15,829,000	8,600	\$ 536,100	\$62
Santa Clara River Hydrologic Unit												
Casitas Reservoir <sup>a</sup>	\$	10,000	\$ 363,200	--	\$	10,000	\$ 363,200	--	\$	10,000	\$ 363,200	--
Conduit	1,670,500	---	127,100	--	1,670,500	---	127,100	--	1,670,500	---	127,100	--
Santa Felicia Reservoir	9,028,700	19,000	468,600	--	---	---	---	--	---	---	---	--
Topatopa Reservoir	---	---	---	--	---	---	---	--	---	---	---	--
Devil Canyon Reservoir <sup>a</sup>	---	---	---	--	15,486,500	27,000	798,100	--	7,316,500	18,000	377,100	--
Santa Clara River Conduit	4,814,900	---	255,400	--	4,919,500	---	260,900	--	4,919,500	---	260,900	--
Fillmore Well Field	338,100	16,000	55,500	--	338,100	16,000	55,500	--	338,100	16,000	55,500	--
Municipal Distribution System	1,317,500	---	94,300	--	1,317,500	---	94,300	--	1,317,500	---	94,300	--
Agricultural Distribution System	<u>3,037,700</u>	---	<u>168,700</u>	--	<u>3,037,700</u>	---	<u>168,700</u>	--	<u>3,037,700</u>	---	<u>168,700</u>	--
Subtotals	\$20,207,400	45,000	\$1,532,800	\$34	\$26,769,800	53,000	\$1,867,800	\$35	\$18,599,800	44,000	\$1,446,800	\$33
Calleguas-Conejo Hydrologic Unit												
Devil Canyon Reservoir <sup>a</sup>	---	---	---	--	---	---	---	--	\$ 8,170,000	20,100	\$ 421,000	--
Piru-Las Posas Diversion Conduit	---	---	---	--	---	---	---	--	6,960,500	---	369,000	--
Spreading works in East Las Posas and Siml Basins	---	---	---	--	---	---	---	--	2,014,200	---	106,800	--
Subtotals	---	---	---	--	---	---	---	--	---	---	---	--
TOTALS	\$36,036,400	53,600	\$2,068,900	\$39	\$42,598,800	61,600	\$2,403,900	\$39	\$51,573,500	72,700	\$2,879,700	\$40

<sup>a</sup>Average annual cost proportioned on basis of yields.

<sup>b</sup>Energy charges presented in Appendix C reduced by \$28,200 because of lesser initial delivery.

TABLE 115

COMPARISON OF ESTIMATED COSTS OF ALTERNATIVE PLANS  
OF WATER SUPPLY DEVELOPMENT, WITH SELECTED INTEREST RATES

Plan	Capital cost	Average annual cost					
		3 per cent basis		4 per cent basis		5 per cent basis	
		Total	: Per acre-foot : : of yield :	Total	: Per acre-foot : : of yield :	Total	: Per acre-foot : : of yield :
I	\$52,086,300	\$2,472,900	\$50	\$2,865,600	\$58	\$3,266,100	\$67
IA	36,036,400	1,811,300	34	2,068,900	39	2,344,500	44
II	58,648,700	2,759,900	49	3,200,600	57	3,651,800	65
IIA	42,598,800	2,098,300	34	2,403,900	39	2,730,200	44
III	67,623,400	3,170,500	47	3,676,400	54	4,197,300	62
IIIA	51,573,500	2,508,900	35	2,879,700	40	3,275,700	45



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Date	Description	Debit	Credit	Balance	Total
1/1	Balance				
1/2	100.00	100.00		100.00	100.00
1/3	200.00	200.00		300.00	300.00
1/4	150.00		150.00	150.00	150.00
1/5	100.00	100.00		50.00	50.00
1/6	50.00		50.00	0.00	0.00
1/7	100.00		100.00	100.00	100.00
1/8	200.00	200.00		0.00	0.00
1/9	100.00	100.00		0.00	0.00
1/10	100.00		100.00	100.00	100.00
1/11	200.00	200.00		0.00	0.00
1/12	100.00	100.00		0.00	0.00
1/13	100.00		100.00	100.00	100.00
1/14	200.00	200.00		0.00	0.00
1/15	100.00	100.00		0.00	0.00
1/16	100.00		100.00	100.00	100.00
1/17	200.00	200.00		0.00	0.00
1/18	100.00	100.00		0.00	0.00
1/19	100.00		100.00	100.00	100.00
1/20	200.00	200.00		0.00	0.00
1/21	100.00	100.00		0.00	0.00
1/22	100.00		100.00	100.00	100.00
1/23	200.00	200.00		0.00	0.00
1/24	100.00	100.00		0.00	0.00
1/25	100.00		100.00	100.00	100.00
1/26	200.00	200.00		0.00	0.00
1/27	100.00	100.00		0.00	0.00
1/28	100.00		100.00	100.00	100.00
1/29	200.00	200.00		0.00	0.00
1/30	100.00	100.00		0.00	0.00
1/31	100.00		100.00	100.00	100.00
2/1	200.00	200.00		0.00	0.00
2/2	100.00	100.00		0.00	0.00
2/3	100.00		100.00	100.00	100.00
2/4	200.00	200.00		0.00	0.00
2/5	100.00	100.00		0.00	0.00
2/6	100.00		100.00	100.00	100.00
2/7	200.00	200.00		0.00	0.00
2/8	100.00	100.00		0.00	0.00
2/9	100.00		100.00	100.00	100.00
2/10	200.00	200.00		0.00	0.00
2/11	100.00	100.00		0.00	0.00
2/12	100.00		100.00	100.00	100.00
2/13	200.00	200.00		0.00	0.00
2/14	100.00	100.00		0.00	0.00
2/15	100.00		100.00	100.00	100.00
2/16	200.00	200.00		0.00	0.00
2/17	100.00	100.00		0.00	0.00
2/18	100.00		100.00	100.00	100.00
2/19	200.00	200.00		0.00	0.00
2/20	100.00	100.00		0.00	0.00
2/21	100.00		100.00	100.00	100.00
2/22	200.00	200.00		0.00	0.00
2/23	100.00	100.00		0.00	0.00
2/24	100.00		100.00	100.00	100.00
2/25	200.00	200.00		0.00	0.00
2/26	100.00	100.00		0.00	0.00
2/27	100.00		100.00	100.00	100.00
2/28	200.00	200.00		0.00	0.00
2/29	100.00	100.00		0.00	0.00
2/30	100.00		100.00	100.00	100.00
2/31	200.00	200.00		0.00	0.00

## CHAPTER V. SUMMARY OF CONCLUSIONS, AND RECOMMENDATIONS

As a result of field investigation and analysis of available data on the water resources and water problems of Ventura County, and on the basis of the estimates and assumptions discussed hereinbefore, the following conclusions and recommendations are made:

### Summary of Conclusions

1. Water resources problems of Ventura County are manifested in the perennial lowering of ground water levels, sea-water intrusion to pumped aquifers, degradation of ground water quality, and general diminution of surface and ground water supplies during periods of drought to quantities inadequate to satisfy requirements.

2. The initial alleviation of the foregoing problems will involve further regulation of the erratic local water supply, so that waste conserved during wet periods can be made available for beneficial use during periods of drought. Final solution of water problems of Ventura County will lie in the importation of water supplies from outside sources.

3. The present principal sources of water supply of Ventura County are direct precipitation and runoff from tributary drainage areas. Imported water constitutes a minor item of water supply. Mean seasonal depth of precipitation in the County varies from a minimum of about 12 inches near the coast to a maximum of about 32 inches in the northerly mountainous area. Mean seasonal runoff to the ocean from the Ventura and Santa Clara Rivers, with the present pattern of land use and water supply development, is about 230,000 acre-feet.

4. Regulation and re-regulation of the water supplies of Ventura County is accomplished almost entirely through storage in underlying ground water reservoirs. Matilija Reservoir is the only significant surface storage reservoir in the County, and direct use of surface water is limited to a relatively few users along the Ventura and Santa Clara Rivers. A total of 17 major ground water basins have been identified in the County, 16 of which are presently of economic importance. Extensive utilization of ground water storage has enabled Ventura County to achieve its present stage of development. The safe yield of the presently developed water supply is about 107,000 acre-feet per season, distributed as follows: Ventura Hydrologic Unit, 9,400 acre-feet; Santa Clara River Hydrologic Unit, 73,200 acre-feet; Calleguas-Conejo Hydrologic Unit, 23,700 acre-feet; and Malibu Hydrologic Unit, 800 acre-feet.

5. Piezometric levels in confined aquifers of the Mound, Oxnard Plain, and Pleasant Valley Basins, were drawn below sea level during the drought period from 1944-45 through 1950-51, and landward gradients from the ocean prevailed therein. In 1951, sea water invaded a portion of the Oxnard aquifer being actively pumped in the Oxnard Plain Basin.

6. Surface and ground water supplies of Ventura County generally are of good mineral quality and suitable for irrigation and other beneficial purposes.

7. The gross area presently requiring water service in Ventura County comprises about 140,000 acres, distributed as follows: Ventura Hydrologic Unit, 12,000 acres; Santa Clara River Hydrologic Unit, 103,000 acres; Calleguas-Conejo Hydrologic Unit, 25,000 acres; and Malibu Hydrologic Unit 500 acres. There are about 235,000 acres in



the County considered susceptible to concentrated and intensive water-using developments.

8. The present mean seasonal water requirement of Ventura County is about 180,000 acre-feet, distributed as follows: Ventura Hydrologic Unit, 13,000 acre-feet; Santa Clara River Hydrologic Unit, 133,000 acre-feet; Calleguas-Conejo Hydrologic Unit, 33,000 acre-feet; and Malibu Hydrologic Unit, 1,000 acre-feet.

9. The probable ultimate water requirement of Ventura County will be about 389,000 acre-feet, distributed as follows: Ventura Hydrologic Unit, 39,000 acre-feet; Santa Clara River Hydrologic Unit, 227,000 acre-feet; Calleguas-Conejo Hydrologic Unit 104,000 acre-feet; Malibu Hydrologic Unit, 14,000 acre-feet; and remainder of the County, 5,000 acre-feet.

10. The present mean seasonal requirement for supplemental water in Ventura County is about 73,000 acre-feet, distributed as follows: Ventura Hydrologic Unit, 4,000 acre-feet; Santa Clara River Hydrologic Unit, 60,000 acre-feet; and Calleguas-Conejo Hydrologic Unit, 9,000 acre-feet. Supplemental water is presently required in the Ventura Hydrologic Unit to eliminate ground water overdraft in Ojai and Upper Ventura River Basins, and to firm the presently erratic and deficient surface water supplies. Supplemental water is presently required in the Santa Clara River Hydrologic Unit to prevent the intrusion of sea water to pumped aquifers in the Oxnard Plain and Pleasant Valley Basins. There is no present requirement for supplemental water in the Piru, Fillmore, and Santa Paula Subunits of the Santa Clara River Hydrologic Unit. Supplemental water is presently required in the Calleguas-Conejo Hydrologic Unit to prevent perennial and progressive

lowering of ground water levels, with attendant degradation of ground water quality, in Simi, East and West Las Posas, and Tierra Rejada Basins.

11. Under forecast ultimate conditions of development in Ventura County, the mean seasonal requirement for supplemental water will be about 266,000 acre-feet, distributed as follows: Ventura Hydrologic Unit, 30,000 acre-feet; Santa Clara River Hydrologic Unit, 142,000 acre-feet; Calleguas-Conejo Hydrologic Unit, 81,000 acre-feet; and Malibu Hydrologic Unit, 13,000 acre-feet.

12. An immediate source of supplemental water is available locally to Ventura County in the surface waters presently wasting to the ocean, the salvage of which will require the development of equalizing storage capacity either in surface reservoirs or in presently undeveloped ground water storage capacity. An immediate source of imported supplemental water is available to the County in waters of the Colorado River, through facilities of the Metropolitan Water District of Southern California. A future source of supplemental water, sufficient in quantity to satisfy those probable ultimate water requirements of Ventura County in excess of the yield of feasible local water supply developments will be available to the County from the Feather River Project.

13. The capital costs of potential surface storage developments in Ventura County vary from about \$4,000,000 to about \$40,000,000, and the average annual unit cost of new water made available by these developments vary from about \$30 to an excess of \$150 per acre-foot. The least expensive development of supplemental water for the County consists of the use of presently undeveloped ground water storage

capacity, which development in the Santa Clara River Hydrologic Unit would involve a capital expenditure of about \$338,000, and would yield about 16,000 acre-feet per season of new water at an average annual unit cost of about \$3.50 per acre-foot. These costs do not consider possible damages to overlying ground water users.

14. Alleviation of present ground water overdraft in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins can be accomplished only by development of a supplemental water supply, either in upstream surface or ground water storage or through importation, and the distribution of this supply in surface conduits to lands in the Oxnard Plain and Pleasant Valley Subunits presently served with ground water. Initially, a supplemental water supply of from 40,000 to 50,000 acre-feet per season should be made available to the Oxnard Forebay, Oxnard Plain and Pleasant Valley Subunits for this purpose.

15. Any conservation reservoirs constructed in the Santa Clara River watershed would be for the primary purpose of furnishing new water to the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit. Such reservoirs should be operated with uniform seasonal releases to meet demands for water in the foregoing subunits. To achieve the maximum benefit, water released from the reservoirs should be conveyed to areas of need in a conduit. A substantial increase in the benefit from surface reservoirs in the Santa Clara River watershed will result if releases therefrom are not made to maintain historic ground water levels in Piru, Fillmore, and Santa Paula Basins.

16. The most favorable dam and reservoir sites in Ventura County, from the standpoints of cost and yield of water, are the Casitas



site on Coyote Creek with reservoir inflow implemented by diversion of water from the Ventura River, the Cold Spring and Topatopa sites on Sespe Creek, and the Santa Felicia and Devil Canyon sites on Piru Creek. The most desirable reservoir storage capacity at the Casitas site is about 130,000 acre-feet; at the Topatopa site, about 100,000 acre-feet; at the Santa Felicia site, about 100,000 acre-feet; and at Devil Canyon site, about 150,000 acre-feet. Because of inadequate data relating to runoff, construction of a dam and reservoir at the Cold Spring site should be postponed until such time as reliable hydrographic data become available, which will enable evaluation of the proper reservoir capacity to be constructed.

17. It is feasible from an engineering standpoint temporarily to divert surplus waters from Casitas Reservoir for interim use in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits of the Santa Clara River Hydrologic Unit.

18. It is feasible from the engineering standpoint to operate a Devil Canyon Reservoir of 150,000 acre-foot storage capacity for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units, and to convey water conserved by the reservoir in a pressure conduit to spreading grounds in Las Posas and Simi Basins of the Calleguas-Conejo Hydrologic Unit. When Feather River Project water is made available to Ventura County, via Piru Creek, a portion of the 150,000 acre-foot storage capacity of Devil Canyon Reservoir could be used for terminal regulation of the imported water. In addition, the foregoing conduit could be utilized to deliver Feather River Project water to the Calleguas-Conejo Hydrologic Unit.

19. Colorado River water could be delivered, through extended facilities of the Metropolitan Water District of Southern California, to terminal regulating reservoirs in Ventura County, at capital costs varying from about \$20,000,000 to about \$54,000,000 for aqueduct capacities of from 25 second-feet to 150 second-feet. The average unit cost of the 18,000 acre-feet per season of Colorado River water delivered by the 25 second-foot capacity aqueduct would be about \$171 per acre-foot. The average annual cost of the 108,000 acre-feet of water per season delivered by the 150 second-foot capacity aqueduct would be about \$58 per acre-foot. These estimates do not include costs of distributing Colorado River water within the County. Average annual unit costs of the water at the terminal reservoirs compare unfavorably with like costs from potential local conservation developments. Furthermore, the works for importation of Colorado River water are not susceptible to staged development. A firm water supply, in an amount sufficient to satisfy present deficiencies in Ventura County and to provide some capacity to meet increased future requirements, could be obtained from the Colorado River, but only at a relatively large initial capital expenditure. This capital cost, under the presently required financial arrangements with the Metropolitan Water District, may be in excess of the present financial capacity of Ventura County.

20. Of the six plans considered for county-wide development of local water resources, the most favorable from the standpoints of yield of new water and capital and unit costs are Plans IA, IIA, and IIIA, which include planned operation of ground water storage capacity in the Santa Clara River Hydrologic Unit. From the standpoint of

service of water to areas of need, Plan IIIA is the most desirable. From the standpoint of watershed development, both Plans IIA and IIIA are superior to Plan IA. Capital cost of Plan IIIA, estimated to be about \$52,000,000 which includes provision of supplemental water for the Calleguas-Conejo Hydrologic Unit, may be beyond the present financial capacity of Ventura County. For this reason, Plan IIIA should be adopted as a staged development, with the features of Plan IIA to be constructed initially, and with the objective of constructing the Piru-Las Posas Diversion as soon as future financial capacity will permit.

Plan IIIA includes a 130,000 acre-foot Casitas Reservoir, the Casitas Distribution System, and the Casitas-Oxnard Plain Diversion. Devil Canyon Reservoir, with 150,000 acre-feet of storage capacity is operated under the uniform release method and without releases to maintain historic ground water levels, for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units. The plan also includes the Piru-Las Posas Diversion, spreading grounds in the Calleguas-Conejo Hydrologic Unit, the Santa Clara River Conduit, the Fillmore Well Field for planned operation of undeveloped ground water storage capacity, and the Oxnard Plain-Pleasant Valley Distribution System. Plan IIA differs from Plan IIIA in that Devil Canyon Reservoir is operated solely for the benefit of the Santa Clara River Hydrologic Unit, and the Piru-Las Posas Diversion and spreading grounds in the Calleguas-Conejo Hydrologic Unit are not included. The estimated capital cost of Plan IIA is about \$43,000,000.

21. Should Plans IA, IIA, and IIIA prove to be infeasible because of legal limitations relating to water rights of overlying ground water users, Plan III would be the most desirable from the



standpoints of yield of new water and service to areas of need. However, the capital cost of this plan estimated to be about \$68,000,000, is believed to be considerably greater than the probable present capacity of Ventura County to finance. For this reason, and under the foregoing legal circumstance, staged development of Plan III should be undertaken. A desirable initial development to this end would include all features of Plan III except for Topatopa Reservoir and the works to provide supplemental water to the Calleguas-Conejo Hydrologic Unit. The capital cost of these initial works would be about \$43,000,000.

Plan III includes a 130,000 acre-foot Casitas Reservoir, the Casitas Distribution System, and the Casitas-Oxnard Plain Diversion. Devil Canyon Reservoir, with 150,000 acre-feet of storage capacity, is operated for the joint benefit of the Santa Clara River and Calleguas-Conejo Hydrologic Units. The plan includes the Piru-Las Posas Diversion and spreading grounds in the Calleguas-Conejo Hydrologic Unit. Topatopa Reservoir, with 100,000 acre-feet of storage capacity, and Devil Canyon Reservoir, are operated under the uniform release method with releases to maintain historic ground water levels. Plan III also includes the Santa Clara River Conduit and the Oxnard Plain-Fleasant Valley Distribution System.

22. Only through the formation of a single county-wide water agency, organized with appropriate powers, can a sound, comprehensive program of water resources development be prosecuted in Ventura County. Such an agency is essential, not only to undertake the development of local water resources, but also to obtain imported water for the County as will be necessary to meet the probable ultimate supplemental water requirement.

### Recommendations

1. That a county-wide water agency endowed with appropriate powers be created in Ventura County for the purpose of financing, constructing, and operating feasible water supply developments.

2. That plans for solution of the water problems of Ventura County be executed in conformity with the conclusions set forth herein.

3. That a program be initiated for the acquisition of lands, easements, and rights of way necessary for construction of feasible water resource development works in Ventura County.

4. That the program of hydrologic investigation by Ventura County be continued and expanded for the purpose of more definitely evaluating the water problems under continuing growth and development of the County.

5. That continuing support be given to the investigation and study of major multi-purpose water resources developments under The California Water Plan, including those relating to importation of water to southern California under provisions of the Feather River Project.

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vol 2

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AGREEMENT, AND ITS SUPPLEMENT, BETWEEN THE STATE WATER RESOURCES BOARD,  
THE COUNTY OF VENTURA, AND THE DEPARTMENT OF PUBLIC WORKS

---

MEMORANDA OF UNDERSTANDING BETWEEN THE DIVISION OF WATER RESOURCES,  
UNITED WATER CONSERVATION DISTRICT,  
AND THE VENTURA COUNTY FLOOD CONTROL DISTRICT

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APPENDIX A

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,  
THE VENTURA COUNTY FLOOD CONTROL DISTRICT,  
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, entered into as of the 15th day of April, 1951, by and between the State Water Resources Board, hereinafter referred to as the "Board", the Ventura County Flood Control District, hereinafter referred to as the "District", and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H:

WHEREAS, by the State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, state agency or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money on behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, the District has requested the Board to enter into a cooperative agreement to conduct a comprehensive investigation of the water resources of Ventura County; and

WHEREAS, the State Engineer has reported to the Board that, as a result of a preliminary investigation it was concluded that emergency water problems exist in Ventura County and that a cooperative investigation is

warranted and within the scope and intent for which matching funds are allocated by the State Water Resources Board; and

WHEREAS, the Board has requested the State Engineer to cooperate in conducting a comprehensive investigation of the water resources of Ventura County and to formulate a report thereon;

NOW THEREFORE, in consideration of the premises and of the several promises to be performed by each as hereinafter set forth, the Board, the District, and the State Engineer do hereby mutually agree as follows:

#### ARTICLE I - WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of (1) a complete review of reports of prior investigations concerning the water resources of Ventura County; (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service agencies, (c) ultimate water requirements, (d) preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent, (e) required supplemental water supply from outside sources, (f) possible outside sources for required supplemental supply including preliminary plans for importation and estimates of costs; and (3) the formulation of a report thereon.

The work shall include the following:

- (a) A plan for the development and utilization of the water resources of Sespe Creek, including features for their use in the Santa Clara River Valley and Oxnard Plain.

- (b) A plan for the development and utilization of the water resources of Piru Creek, including features for their use in the Santa Clara Valley and Oxnard Plain.
- (c) A plan for meeting the present and future needs of Calleguas Creek Basin either from Santa Clara River Basin or from other sources.
- (d) A plan for the development and utilization of the water resources of the Ventura River and tributaries including their use in the Ventura River Basin.

In connection with the study of dam and reservoir sites on streams of Ventura County, the following work shall be undertaken initially:

- (a) Devil's Canyon site on Piru Creek--water testing of dam foundation;
- (b) Topa Topa site on Sespe Creek--exploration of dam site and borrow areas;
- (c) Fillmore site on Sespe Creek--exploration of dam site and borrow areas and topographic survey of dam and reservoir sites.

The Board by this agreement authorizes and directs the State Engineer to cooperate by conducting said investigation and formulating said report and by otherwise advising and assisting in formulating solutions to the water problems in Ventura County.

During the progress of said investigation, all maps, plans, information, data and records pertaining thereto which are in the possession of any party hereto, shall be made fully available to any other party hereto for the due and proper accomplishments of the objectives hereof.

The work to be done under this agreement shall be diligently prosecuted with the objective of completing the investigation and report on or before June 30, 1953. A progress report containing findings on possible development of surface water supplies of Sespe and Piru Creeks shall be completed by February 1, 1952, or as soon thereafter as possible.



## ARTICLE II - FUNDS:

On execution of this agreement, the District shall transmit the sum of Five Thousand Dollars (\$5,000) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also upon execution of this agreement, the Board shall request the Director of Finance to approve the transfer of the sum of Five Thousand Dollars (\$5,000) from funds appropriated to the Board by Item 257 of the Budget Act of 1950 to the said Water Resources Revolving Fund for expenditure by the State Engineer in performance of work provided for in this agreement.

On or before July 1, 1951, the District shall transmit the further sum of Fifteen Thousand Dollars (\$15,000) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Following July 1, 1951, as soon as practicable the Board shall request the Director of Finance to approve the transfer of the further sum of Fifteen Thousand Dollars (\$15,000) to said Water Resources Revolving Fund from any funds which may be made available for such purposes, for expenditure by the State Engineer in performance of the work provided for in this agreement.

In the event that on or before July 1, 1952, the District shall transmit the sum of Ten Thousand Dollars (\$10,000) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement,

thereupon as soon as practicable the Board shall request the Director of Finance to approve the transfer of the sum of Ten Thousand Dollars (\$10,000) to said Water Resources Revolving Fund from any funds which may be made available for such purposes, for expenditure by the State Engineer in performance of the work provided for in this agreement.

Of the funds made available under this agreement, not more than Ten Thousand Dollars (\$10,000) shall be expended on exploration work and surveys at dam and reservoir sites.

Notwithstanding anything contained in this agreement contrary hereto or in conflict herewith, this agreement is made contingent upon the funds being deposited in or transferred to the Water Resources Revolving Fund as provided herein for expenditure by the State Engineer in performance of the work provided for in this agreement. In the event any of the funds are not transferred to the Water Resources Revolving Fund by the Director of Finance as provided for herein within 30 days after the Board requests such transfer, this agreement shall terminate and the unexpended balance of any funds deposited by the County shall be returned, provided that neither the Board nor the State Engineer shall be obligated to the County for any portion of the funds already expended.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder.

Upon completion and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to the Board and one-half of the total

amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board and to the County in equal amounts.

Notwithstanding anything herein contained to the contrary, this agreement may be terminated and the provisions of this agreement may be altered, changed, or amended, by mutual consent of the parties hereto.

IN WITNESS WHEREOF, the parties hereunto have executed this agreement as of the date first herein written.

Approved as to Form:

VENTURA COUNTY FLOOD CONTROL DISTRICT

/s/ Roy A. Gustafson  
Attorney, Ventura County  
Flood Control District

By /s/ R. E. Barrett  
Chairman, Board of Supervisors

S  
E  
A  
L

Approved as to Form  
and Procedure

STATE WATER RESOURCES BOARD

/s/ Henry Holsinger  
Attorney for Division  
of Water Resources

By /s/ Royal Miller  
Member

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS

C. H. PURCELL

Director of Public Works

By

/s/ Frank B. Durkee  
Frank B. Durkee  
Deputy Director

S  
E  
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L

APPROVED:

/s/ James S. Dean  
Director of Finance

/s/ A. D. Edmonston  
A. D. Edmonston  
State Engineer

:E.J.R.:F.J.M.: : :  
: Form :Budget:Value:Descript.:  
: DEPARTMENT OF FINANCE :  
: A P P R O V E D :  
: May 7 1951 :  
:



SUPPLEMENTAL AGREEMENT  
BETWEEN  
THE STATE WATER RESOURCES BOARD,  
THE VENTURA COUNTY FLOOD CONTROL DISTRICT, AND THE  
DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into as of May 1, 1952, by the State Water Resources Board, hereinafter referred to as the "Board"; the Ventura County Flood Control District, hereinafter referred to as the "District"; and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer".

W I T N E S S E T H:

WHEREAS, by agreement heretofore entered into as of April 15, 1951, by and between the District, the Board, and the State Engineer, it was provided that the work to be performed by the State Engineer thereunder shall consist of (1) a complete review of reports of prior investigations concerning the water resources of Ventura County; (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service agencies, (c) ultimate water requirements, (d) preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent, (e) required supplemental water supply from outside sources, (f) possible outside sources for required supplemental supply including preliminary plans for importation and estimates of costs; and (3) the formulation of a report thereon; and

WHEREAS, under said agreement the District made available the sum of Five Thousand Dollars (\$5,000) and Fifteen Thousand Dollars (\$15,000) which were matched in equal amounts by the Board for expenditure by the State Engineer in the performance of the work provided for in said agreement; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the second year of said investigation the District would make available a further sum of Ten Thousand Dollars (\$10,000) subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report; and

WHEREAS, the funds provided for under said prior agreement, to which this agreement is supplemental, have been exhausted and additional funds are now required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Twenty Thousand Dollars (\$20,000) shall be provided, Ten Thousand Dollars (\$10,000) by the District and Ten Thousand Dollars (\$10,000) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the District, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Ten Thousand Dollars (\$10,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Ten Thousand Dollars (\$10,000) from funds appropriated to the Board by Item 269 of the Budget Act of 1952 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Sixty Thousand Dollars (\$60,000) as made available under said prior agreement and this supplemental agreement and if funds are exhausted before completion of said work the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the completion thereof.

4. In so far as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.



Approved as to Form and  
Procedure

VENTURA COUNTY FLOOD CONTROL DISTRICT

/s/ Donald H. Benton  
Attorney, Ventura County  
Flood Control District

By /s/ R. E. Barrett  
Chairman, Board of Supervisors

Approved as to Form and  
Procedure

STATE WATER RESOURCES BOARD

/s/ Henry Holsinger  
Attorney for Division of  
Water Resources

By /s/ B. A. Etcheverry  
Vice Chairman

Approved as to Form and  
Procedure

State of California  
Department of Public Works

Attorney, Department of  
Public Works

FRANK B. DURKEE  
Director of Public Works

By /s/ Russell S. Munro

APPROVED:

/s/ James S. Dean  
Director of Finance

/s/ A. D. Edmonston  
A. D. Edmonston  
State Engineer

:L.E.Z.:F.J.M.: :  
: Form :Budget:Value:Descript.:  
: DEPARTMENT OF FINANCE :  
: A P P R O V E D :  
: May 19 1952 :  
:

MEMORANDUM OF UNDERSTANDING

WITH REFERENCE TO WATER RESOURCES INVESTIGATION OF VENTURA COUNTY

The objective of this memorandum of understanding is to coordinate the work of the State of California, Ventura County Flood Control District, and the United Water Conservation District in the investigation of the water problems in the County of Ventura and the formulation of plans for their solution.

It is contemplated that an agreement will be executed between the State Water Resources Board, the Ventura County Flood Control District, and the Department of Public Works acting through the State Engineer for the purpose of conducting a county-wide comprehensive investigation of the water resources of Ventura County.

This memorandum is a prerequisite of the execution of the aforesaid agreement.

This memorandum sets forth only that part of the county-wide investigation in which all three of the named agencies are interested. Other parts of the county-wide study will go forward simultaneously under plans approved by the State and the District, and work primarily of interest to the Conservation District will be done and/or paid for by that agency. However the work of all agencies shall be closely coordinated, and information shall be freely exchanged. Any work done by the Conservation District with funds furnished by the Flood Control District shall be of sufficient scope to serve the purposes of the county-wide survey, as determined by the State Engineer.

This memorandum is preliminary in nature and shall be revised as necessary as the work proceeds, and all revisions shall be approved by representatives of the State, Flood Control District and Conservation District.

1. General Water Supply Studies

a. State

1. Geologic investigation of Santa Clara River Basin and Oxnard Plain, including Pleasant Valley. Any geologic work beyond that which the State does shall be paid for by whatever agencies request additional work.
2. Water supply available from all streams in Santa Clara Basin.
3. Method of utilization of conserved water.

b. United Water Conservation District

1. Make an independent check on previously reported values on water supply available at various reservoir sites on Sespe and Piru Creeks.
2. Make yield studies of reservoirs under consideration on Sespe and Piru Creeks in conjunction with utilization of ground water storage, up to maximum practicable capacity at each site.
3. Determine a method of conservation and determine location, capacity and size of spreading grounds in the Santa Clara River Basin.

2. Dam and Reservoir Site Investigations

a. Sespe Creek

1. Fillmore Site, approximately two miles above Telegraph Road.

(a) State

Locate drill holes and obtain rig and drill churn drill holes, obtain and operate geophysical rig for determining seismic profile and make a geological report.



Study availability of materials suitable for an earthfill dam of maximum planned height.

(b) Ventura County Flood Control District

Topographic survey and map of dam site, Scale 1" = 200', contour interval 5', to a height of 400' above stream-bed. Survey to be tied into U.S.G.S. surveys. Contour at an elevation of approximately 200' above stream-bed at dam site, to be located and mapped in order to check new U.S.G.S. sheet of this area.

Locate all cultures in dam and reservoir site and estimate cost of acquisition of lands. Calculate height, capacity and surface area curves for reservoir using new U.S.G.S. sheet. Obtain permissions to enter on lands for purpose of drilling holes or seismic work.

(c) United Water Conservation District

If this site is found feasible geologically, make preliminary designs and cost estimates for several heights of dam.

2. Hammel Site

(a) State

Make geological investigation of dam site. Investigate availability of materials.

(b) Ventura County Flood Control District

Provide topographic maps of reservoir and dam sites. Make estimate of cost of acquisition of lands and right of way.

(c) United Water Conservation District

Make preliminary designs and cost estimates for several heights of dams.

3. Topa Topa Site

(a) State

Investigate geology and availability of materials.

(b) Ventura County Flood Control District

Make estimate of cost of acquisition of lands and/or right of way.

(c) United Water Conservation District

Make preliminary designs and cost estimates for several heights of dam.

4. Cold Spring Site

(a) State

Investigate geology and availability of materials.

(b) Ventura County Flood Control District

Make estimate of cost of acquisition and right of way.

(c) United Water Conservation District

Make preliminary designs and estimates of cost for several heights of dam.

b. Piru Creek

1. Devil Canyon Site

(a) State

Investigate geology and availability of materials.

(b) Ventura County Flood Control District

Provide maps of reservoir and dam site. Make estimate of cost of acquisition of lands and right of way.

(c) United Water Conservation District

Make preliminary designs and estimates of cost for several heights of dam.

c. Santa Paula Creek

1. Ferndale site

(a) State

Make estimate of flood control benefits. Make estimate of conservation benefits. Investigate geology and availability of materials.

(b) Ventura County Flood Control District

Make topographic survey and map of dam site, scale 1" = 100', contour interval 5', to a height of 300' above stream-bed. The new U.S.G.S. sheet will be used to calculate a height, capacity and surface area curve for this dam. Make estimate of cost of acquisition of lands and right of way.

(c) United Water Conservation District

Make preliminary designs and estimates of costs for several heights of dam.

As soon as the most satisfactory dam site or dam sites are decided upon in the Santa Clara River Basin, United Water Conservation District will proceed with detailed investigation of said sites. Such investigation, if paid for with funds advanced by the Ventura County Flood Control District, shall be sufficiently broad to cover the needs of the county-wide investigation.

All work outlined herein to be done by the State of California and by the Ventura County Flood Control District is to be paid from funds to be



made available under the aforementioned cooperative agreement between the State Water Resources Board, the Ventura County Flood Control and the State Engineer. Work to be done by United Water Conservation District will be paid for from funds provided by that agency.

April 23, 1951

/s/ A. D. Edmonston  
A. D. Edmonston, State Engineer

April 24, 1951

/s/ Robert L. Ryan  
Robert L. Ryan,  
County Surveyor  
Ventura County

April 23, 1951

/s/ Julian Hinds  
Julian Hinds,  
Consulting Engineer  
United Water Conservation District

MEMORANDUM OF UNDERSTANDING  
With Reference to Water Resources Investigation of Ventura County

---

A memorandum of understanding was entered into on April 23 and 24, 1951, between representatives of the State Division of Water Resources, the Ventura County Flood Control District, and the United Water Conservation District, with the objective of coordinating the work of the three agencies in the investigation and study of the water problems of Ventura County. The Memorandum set forth the part of the coordinated program each agency would perform in the investigation and the cooperation that would be effected in the exchange of data so that there would be a minimum of duplication of effort and so that completion of the work would be effected as expeditiously as possible. Such coordination has been effectively carried out.

A meeting of the representatives of the foregoing three agencies was held in the office of the State Engineer on September 29 and 30, 1952, for the purpose of reviewing the results so far accomplished by the three agencies and to program certain further work to be done. At the conclusion of said meeting it was mutually agreed that both the United Water Conservation District and the State Division of Water Resources would:

1. Prepare independent cost estimates for concrete arch dams at the Topa Topa site on Sespe Creek to create gross storage of water in the amounts of 50,000 acre-feet, 75,000 acre-feet, and 100,000 acre-feet respectively.
2. Review existing yield studies for reservoirs created by the foregoing sizes of dams on the Topa Topa site on Sespe Creek.
3. Review existing yield studies for a reservoir of 100,000 acre-foot storage capacity at the Santa Felicia site on Piru Creek.

Said work to be accomplished by October 15, 1952, the results thereof to be submitted to the other parties to this agreement on or about that date, and a further meeting between the parties to be held in Santa Paula on October 24, 1952.

It was also mutually agreed, based on preliminary information available, that a rolled earth-fill type of dam is suitable and appropriate for the Santa Felicia site on Piru Creek, and that the capacity of Santa Felicia Reservoir should be limited to a maximum storage capacity of about 100,000 acre-feet in order to preserve from inundation the upstream Blue Point Dam and Reservoir site and to permit future development of said Blue Point site.

It was further mutually agreed that any dam constructed at the Topa Topa site on Sespe Creek should preferably be built initially to the maximum practicable size without provision for future enlargement.

/s/ A. D. Edmonston  
A. D. Edmonston, State Engineer

/s/ Robert L. Ryan  
Robert L. Ryan, County Surveyor  
Ventura County

/s/ Julian Hinds  
Julian Hinds, Consulting Engineer  
United Water Conservation District

Sacramento, California  
October 1, 1952



MEMORANDUM OF UNDERSTANDING

With Reference to Water Resources Investigation of Ventura County  
November, 1952

---

Pursuant to a memorandum of understanding entered into on October 1, 1952, by representatives of the State Division of Water Resources, the Ventura County Flood Control District, and the United Water Conservation District, a meeting was held in the offices of the United Water Conservation District in Santa Paula on October 24, 1952, among representatives of the foregoing agencies. Under terms of the aforementioned memorandum of understanding, both the United Water Conservation District and the State Division of Water Resources were to prepare estimates of cost for concrete arch dams at the Topa Topa site on Sespe Creek creating reservoir capacities of 50,000, 75,000, and 100,000 acre-feet, respectively, and to review existing yield studies for reservoirs of these capacities. In addition, existing yield studies for a reservoir of 100,000 acre-feet capacity at the Santa Felicia site on Piru Creek were also to be reviewed.

As a result of these studies and in accordance with the conclusions derived and concurred in by the attendant parties at the meeting of October 24, 1952, it is mutually agreed that:

1. The reservoir yields independently determined under terms of the memorandum of understanding, dated October 1, 1952, are in agreement.
2. A fill type dam will be constructed at the Santa Felicia site on Piru Creek creating a gross reservoir capacity of not less than 90,000 acre-feet nor more than 100,000 acre-feet.
3. A concrete arch dam, creating a gross reservoir capacity of not less than 50,000 acre-feet, will be constructed at the Topa Topa site on Sespe Creek.

4. The United Water Conservation District will prepare plans and call for bids for construction of concrete arch dams at the Topa Topa site, which would create reservoir capacities of 50,000 and 60,000 acre-feet, with the objective of constructing as large a capacity reservoir as financial limitations will permit.

5. The State Division of Water Resources will study and report on the feasibility of an overpour spillway for concrete arch dams at the Topa Topa site for gross reservoir capacities of 50,000 acre-feet and larger.

6. Construction of not less than 90,000 acre-feet nor more than 100,000 acre-feet of gross reservoir storage capacity at the Santa Felicia site on Piru Creek, and of not less than 50,000 acre-feet of gross reservoir storage capacity at the Topa Topa site on Sespe Creek, is consistent with an overall plan for the conservation and utilization of the water resources of Ventura County.

/s/ A. D. Edmonston  
A. D. Edmonston, State Engineer

/s/ Robert L. Ryan  
Robert L. Ryan, Engineer  
Ventura County Flood Control District

/s/ Julian Hinds  
Julian Hinds, Consulting Engineer  
United Water Conservation District

APPENDIX B

GEOLOGY AND GROUND WATER OF  
VENTURA COUNTY, CALIFORNIA



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## CHAPTER B-I. INTRODUCTION

Ventura County includes an area of approximately 1,857 square miles which is bounded by surveyed lines chosen irrespective of watershed boundaries or geologic features, except along its southwest and in part its west sides. The southwestern boundary is the Pacific Ocean.

This appendix includes a description of the geology of Ventura County and adjacent areas with particular emphasis placed upon those geologic features which influence the occurrence and movement of ground water. Its purpose is threefold, namely:

1. To describe the geology and water-bearing properties of the rocks.
2. To discuss the effects of geologic structure upon the movement of ground water and the infiltration of sea water, and to describe briefly the history of events involving the evolution of the principal structures.
3. To describe the procedures followed in estimating the changes in ground water storage and estimating sub-surface ground water movement that occurred within the principal basins during selected periods of study.

The older less permeable formations which yield little water are treated briefly. These rocks are mentioned because: they are the parent source of sediments which fill the ground water basins, in certain localities they affect the chemical character of the ground water, their position in part controls the movement and occurrence of ground water, and they form or delimit the ground water basins.

The permeable water-bearing formations are described in greater detail. These deposits comprise the fill of the ground water basins, the principal sources of ground water supply in the County.

Subsurface ground water geology was interpreted largely from the logs of some 1,534 water wells, most of which were obtained from the Ventura County Water Survey and some from field canvass. Considerable shallow subsurface data



in the form of 138 electric logs, drillers logs, and core descriptions were obtained from the State Division of Oil and Gas and from oil companies operating in various areas. Ground water level data and water analyses were amassed and in certain areas the transmissibility of sediments was estimated by pump testing of wells. All of these data were drawn upon freely in interpreting the geology

A perusal of geologic literature revealed a number of maps and reports prepared by earlier investigators covering various parts of the County. These existing data were drawn upon freely in the preparation of this report and are listed in the accompanying bibliography.

In the course of this investigation, two geologic maps were prepared by compiling data from existing geologic maps, from aerial photographs and from field mapping by the Division of Water Resources in areas where existing data were insufficient. One of these maps is of small scale and depicts the entire County and tributary drainage areas (Plate 10); the second is a detailed map covering the area containing the ground water basins (Plates B-1A, B-1B, and B-1C).

## CHAPTER B-II. PHYSIOGRAPHY

The southern portion of Ventura County is to a large extent located in the Transverse Ranges geomorphic province, while that portion north of the Santa Ynez fault (see Areal Geology, Plate 10) is in the southerly section of the Coast Ranges province (Jenkins 1943). The mountains and valleys in the southern portion of the County trend nearly east-west, while in the northern portion of the County they trend more in a northwest-southeast direction. The physiography of the County can best be described by covering the following features: mountains, valley areas, the coastal plain, and submarine topography.

### Mountains

The principal mountains in Ventura County include the Piru Mountains (named by Axelrod, 1950), the Santa Ynez Mountains, the Topatopa Mountains and the Santa Monica Mountains. Smaller mountain areas include Oak Ridge, the Santa Susana Mountains north of the Simi Valley area, and the Simi Hills south of Simi Valley. All mountain areas are generally maturely dissected and rugged, with relief ranging from 500 to 2,000 feet. Soil cover is generally thin, but some areas of rolling topography are found where soil cover becomes quite thick. Such areas are generally found in the higher parts of the ranges and may represent remnants of one or more old erosion surfaces.

### Valley Areas

In general, many of the valleys were formed under earlier geologic conditions when the area was nearer base level (in most cases sea level). Since being formed most of the valleys have been uplifted and have undergone additional erosion. Generally, cycles of erosion and alluviation have been repeated. A few of the valleys are largely the result of structural movements.

The Santa Clara River Valley is the most prominent valley in Ventura

County and trends east-west. It is controlled essentially by structural features. In general, it is a downfolded and faulted trough between mountains to the north and south. Deposition by the Santa Clara River and by smaller tributaries has been fairly continuous in most of the valley, while terraces on the side slopes may be due in part to periodic uplift of the sides of the valley with respect to the valley floor.

Physiography of the Ventura River drainage area has been discussed in considerable detail by Putnam (1942). Streams in Ojai Valley and the Coyote Creek drainage evidently originally drained westward and eastward respectively toward the Ventura River. Headward erosion of San Antonio and Coyote Creeks has captured those drainages so that they now drain in a southerly direction. Ojai Valley is in a structural depression in which over 700 feet of fluviatile sediments have been deposited. The Coyote Creek drainage area is also in a structural depression, but apparently the area has not been as active as the Ojai Valley area and only thin deposits of alluvium are found there.

The small Upper Ojai Valley, according to Putnam (1942), originally drained westward and the headwaters included the upper portion of the present Santa Paula Creek. Most of the alluvial material now found in Upper Ojai Valley was deposited at that time. Subsequent headward erosion of Santa Paula Creek, possibly aided by tectonic movements, has resulted in the capture of the present drainage system, so that Upper Ojai Valley now drains both to the west and to the east.

The north-south trending Ventura River Valley has been essentially an erosional feature, a relatively small thickness of alluvial fill being found in the valley at the present time. Terrace deposits indicate that the valley has undergone at least two cycles of erosion. Putnam (1942) presents evidence that the most prominent of the terraces has been gently warped upward, with the axis of the upwarping near Casitas Springs.



The Las Posas upland area extends eastward from Oxnard Plain almost to Simi Valley, and lies between Oak Ridge to the north and the Camarillo and Las Posas Hills to the south. This broad upland area slopes generally to the south. Both erosion and deposition are occurring in places within the area at the present time. It is possible that Arroyo Las Posas once flowed westward from the vicinity of Somis, north of the Camarillo Hills, to the Oxnard Plain. If so, it was probably diverted south at Somis into the valley it presently occupies by the building-up of alluvial fans extending from Oak Ridge in the area northwest of Somis.

Simi Valley is located in a structurally depressed area in which over 100 feet of alluvial sediments has accumulated. Simi Valley has been through more than one cycle of erosion as indicated by the exposure and present dissection of the older alluvium on the southwest side of the valley. The Simi fault, extending along the north side of the valley, has apparently been active during deposition of most of the alluvial fill. This is inferred from the 60-foot thickness of the alluvium in the valley just west of where the Simi fault crosses the alluvium. This area is north of the Simi fault or on the uplifted side. The bulk of Simi Valley and the greatest thickness of sediments is south of the Simi fault.

Conejo Valley is a broad valley which has been a part of a larger generally east-west valley system lying in part in Los Angeles County. This old valley system was evidently originally developed by a through stream flowing either east or west. The former drainage system has been captured by headward erosion of Conejo Creek in Conejo Creek Canyon north of Newbury Park, aided by probable northward tilting of the Conejo Valley area and fracturing of rocks.

Tierra Rejada and Santa Rosa Valley are both essentially erosional features, although up to 200 feet of alluvium has been deposited in Santa Rosa Valley. The harder portions of the existing volcanic rocks have created temporary base levels resulting in erosion of Tierra Rejada and another smaller

valley in the upper drainage of Santa Rosa Valley.

There are several other valley areas in Ventura County which are not described here since they lie outside that portion of the County with which this report is principally concerned.

### Coastal Plain

The Coastal Plain has been formed by deposition of sediments from the Santa Clara River and from the Calleguas-Conejo drainage area. The land surface resembles a large compound alluvial fan having one apex near Saticoy and another near Somis. A group of smaller, but steeper, alluvial fans has been deposited by the smaller creeks draining the hills north of the area, forming an alluvial piedmont. Remnants of terraces along the northern edge of the coastal plain indicate uplift of this part of the plain. This rise might be due to relatively recent upwarping in the Ventura River drainage area (Putnam 1942) possibly augmented by changes of sea level.

### Submarine Topography

Principal features of offshore topography are shown on Plate B-3 which is taken from U. S. Coast and Geodetic Survey chart number 5202 (Point Dume to Purisima Point). These features are also discussed in papers by Emery and Shepard (1945) and Emery and Rittenberg (1952). Santa Rosa, Santa Cruz and Anacapa Islands are extensions of the Santa Monica Mountains. A scarp-like feature extends in an east-west direction on the south side of the islands and the Santa Monica Mountains. This scarp is cut by the southerly trending Hueneme and Mugu submarine canyons which end in the floor of the Santa Monica submarine basin lying south of the Santa Monica Mountains. In addition to these major canyons, three poorly developed or incipient canyons exist between the two major canyons. The Santa Barbara basin lies due west of the Coastal Plain of Ventura County. This basin is relatively shallow and the slope of the surface west of

the Oxnard Plain is gentle, being as low as five to fifteen feet per mile. In comparison, the slopes of the east-west scarp and the heads of the submarine canyons are quite steep. Hueneme Canyon cuts across the southeastern corner of the gently sloping Santa Barbara basin.

The heads of the submarine canyons are within a quarter of a mile of the shore, and water-bearing materials are probably exposed along the canyon walls, allowing free contact between sea water and permeable formations. This contact is very important in considering movement of ground water, since, depending on the direction of the gradient, fresh water can be discharged into the ocean or sea water may move into the aquifers.



## CHAPTER B-III. GEOLOGIC FORMATIONS

General descriptions of all geologic formations and a short discussion of their role in the hydrology of Ventura County are included in this section.

The detailed geologic maps of the southern part of Ventura County (Plates B-1A, B-1B, and B-1C) show the areal extent and distribution of formations based on lithology. Plate 10 is a generalized geologic map of the entire Ventura County and Santa Clara River drainage area. The stratigraphic columns Plate B-2 indicate the age relationship between the various formations by area.

The complex geology of Ventura County has been mapped by many people over a period of more than forty years. As a result, present terminology is somewhat confusing to those not familiar with the problems of the area. An attempt has been made in this report to use names of formations which are commonly accepted by local geologists. Wherever lack of agreement seemed to exist the formation names which appeared to be most familiar to local geologists were adopted.

### Basement Complex

The basement complex is composed of granitic and metamorphic rocks of pre-Cretaceous age. The metamorphic rock types include gneiss, schist, hornfels, quartzite, and limestone, indicating that the rocks, before they were metamorphosed, were mostly sediments. These metamorphic rocks were intruded in Jurassic (?) time by granitic and dioritic rocks (Kew 1924, Wallace 1949, and Crowell 1950 and August and October, 1952 and others).

Large areas of the Piru Creek-Santa Clara River drainage area are underlain by deeply weathered granitic and dioritic rocks. Both the igneous and metamorphic rocks are fractured and jointed, being more extensively fractured near large faults.

The basement complex is essentially nonwater-bearing, but scattered

domestic and stock wells obtain small quantities of water from weathered residual materials and from fractures. Small springs are fairly common in areas of basement complex, especially during wet periods.

Surface water derived from areas of basement complex is generally a calcium bicarbonate type with moderately low dissolved solids.

### Cretaceous System

Consolidated sediments of Cretaceous age in the Ventura Region have been called the Chico formation by early workers, but oil company geologists in the last few years have generally dropped this term. Since the formations have not been assigned local names, they are generally called Upper Cretaceous rocks, or simply Cretaceous rocks. The rocks consist of marine shales, siltstones, sandstones, and conglomerates having an aggregate thickness in excess of 7,000 feet. The shales and siltstones are generally well bedded and dark gray to black in color. Upon weathering, they splinter, ultimately disintegrating to gray clayey soils. The sandstones are mostly medium to coarse grained, arkosic, locally micaceous, dark gray in color, and wherever weathered they are usually gray or white. Most exposures show the rocks to be well cemented and indurated; although in some areas the degree of cementation is slight.

The Upper Cretaceous rocks in the Simi Hills are essentially massive sandstones with thin interbedded shales (Kew 1924; Stipp 1943). In the Santa Inez Mountains and in a small area of the Piru Mountains, they consist of thin beds of shale, siltstone, sandstone, and lenticular conglomerates. Conglomerates in the Wheeler Springs area contain well rounded, well cemented sandstone, granitic and metamorphic pebbles (Merrill 1952). The Upper Cretaceous rocks are generally folded and faulted and exhibit complex fracture and joint systems.

Fossils found in this series include Baculites chicoensis and other marine invertebrates indicative of the age of the rocks.

The Upper Cretaceous rocks are generally nonwater-bearing. In the hills south and east of Simi Valley, however, water wells obtain domestic and limited irrigation supplies from the massive poorly cemented and fractured sandstones. A well drilled into one of the sandstones has yielded over 1,000 gallons per minute probably from fracture systems. Small springs generally occur near fractures and faults in the Santa Ynez Mountains. Most of the springs yield cool, fresh water; but some of them which may be associated with faults such as Wheeler Hot Springs, produce warm water of good quality which is generally low in mineral constituents except boron. Surface water from areas of outcrop of these rocks is generally of good quality.

#### Paleocene-Eocene Series

Several formations are included in this series in Ventura County. The Martinez formation comprises the oldest rocks of the series. This formation is found in the Piru Creek area (Clements 1937), the Castaic Creek area (Clements 1937 and Dehlinger 1952), and in the Santa Monica Mountains, but has not been differentiated on Plate 10. In these areas, the Martinez formation consists of marine shale, sandstone, and conglomerate.

The Santa Susana-Martinez formation of Paleocene and middle and lower Eocene age (Stipp 1943) in the Simi Hills and on the south side of Simi Valley consists of up to 3,500 feet of light colored sandstone, some interbedded shale and a massive basal conglomerate. The lower Llajas formation (Meganos of Kew 1924) consists of about 2,000 to 3,000 feet of olive drab and blue shale, minor interbedded sandstone, and a basal conglomerate. The upper Llajas formation (Tejón formation of Kew 1924) consists of about 2,000 feet of brown to gray micaceous sandstone, siltstone, and some conglomerate (Stipp 1943). Both the upper and lower Llajas formations are exposed in the Simi Hills, and are of middle Eocene age.

The formations described below are all exposed north of the Santa Clara



River Valley and are of upper Eocene age. The Juncal formation consists of  
 about 5,000 feet of marine olive drab to grey siltstone and shale grading down-  
 ward into concretionary dark grey siltstone and shale. Near the base of the  
 Juncal formation, there is a black calcareous shale which is the equivalent of  
 the Sierra Blanca limestone in Santa Barbara County (Merrill 1952). The Matilija  
 sandstone lies conformably on the Juncal and consists of about 2,400 feet of  
 marine light colored sandstone with minor interbedded grey siltstone. The Cozy  
 Dell shale lies conformably over the Matilija sandstone and consists of about  
 800 feet of olive drab to grey siltstone and shale. North of the Santa Ynez  
 fault, a prominent mapable white sandstone member has been included within the  
 Cozy Dell (Merrill 1952). Coldwater sandstone conformably overlies the Cozy Dell  
 shale. It consists of about 2,200 feet of white massive sandstone with inter-  
 bedded red and green silty shale and lenticular conglomerate.

In the extreme northwest part of Ventura County a series of brackish  
 water and marine sandstones and shales of Eocene age have been named the Patti-  
 ay formation (Carlson 1952, Dibblee 1952).

Index fossils commonly found in the Paleocene-Eocene formations are  
 listed below:

Santa Susana-Martinez formation	<u>Turritella pachecoensis</u> <u>Venericardia venturensis</u>
Upper and lower Llajas formations	<u>Turritella lawsoni</u> . <u>Galeodea susanae</u>
Juncal formation, Matilija sandstone, Cozy Dell shale, and Coldwater sandstone	<u>Turritella andersoni</u> <u>Turritella uvasana</u>

Shales of the Paleocene-Eocene series are generally well indurated, and the sandstones are fairly well cemented. The entire series generally forms rugged topography with thin sandy soils. Sandstone beds form particularly massive outcrops and very rugged topography. Rocks of this series are strongly fractured, faulted, and folded. They are generally nonwater-bearing. However, in the hills south and east of Simi Valley domestic and limited irrigation supplies are obtained from poorly cemented sandstones of the upper Lajas and the Santa Susana-Martinez formations. Occasional windmills in the Santa Ynez, Topatopa, and Piru Mountain regions obtain water from the sandstone members of this series. Generally, wells tapping these rocks at depths exceeding 300 to 400 feet encounter water of poor quality. Small springs are generally found in these rocks in the region north of the Santa Clara River.

Surface water derived from areas of outcrop of the Paleocene-Eocene series is generally of calcium sulphate type with about 600 to 1,500 and above parts per million (ppm) total dissolved solids.

#### Oligocene Series

The Oligocene series in the Ventura County region consists of continental lenticular interbedded conglomerate, sandstone, and shale. No Oligocene marine deposits are known to exist in the area covered by the geologic maps. The sandstones are poorly to well cemented and generally buff to grey in color. Conglomerates generally contain granitic, metamorphic, sandstone, and chert pebbles and cobbles in a matrix of sandstone or siltstone. The siltstones and shales are generally micaceous and red, maroon, blue, or grey in color. The formation generally weather into red sandy clay soils which are characteristic of areas of outcrop of the series.

In most of Ventura County, the Oligocene series is called the Sespe formation. In the eastern Santa Clara River drainage area, it has been called

the Vasquez formation (Sharp 1935). Beds of probable Oligocene age in the extreme northern part of the County have been called the Simmler formation (Libbelle 1952).

The Sespe formation varies in thickness from 1,200 to 7,300 feet and ranges in age from upper Eocene to lower Miocene, as determined by vertebrate fossils (Bailey 1947).

The Vasquez formation is of lower Miocene and Oligocene age (Jahns 1940) and is up to 9,000 feet thick with about 4,000 feet of interbedded basaltic flows near its base. The Simmler formation is about 3,000 feet thick and contains intrusive andesites in the Lockwood Valley area.

The Oligocene series is essentially nonwater-bearing. Sandstones and conglomerates in the Ojai region and in the Simi Valley area usually yield from 10 to 100 gallons per minute to wells. One well in the sandstones northwest of Simi Valley, however, yields up to 700 gallons per minute. Wells deeper than 100 or 500 feet generally obtain brackish water unsuitable for irrigation.

Surface waters derived from outcrop areas of the Oligocene series are generally of a calcium and bicarbonate-sulphate type with about 300 to 800 ppm total dissolved solids. In Lockwood Valley and in the Tick Canyon area in Los Angeles County, a borax mineral, colemanite, is commonly interbedded with the sediments, and as a result, surface runoff from these areas may be high in boron content especially during periods of low flow.

#### Miocene Series

The Miocene series in the Ventura County region consists of several marine and non-marine formations, and includes volcanic rocks. Reference may be made to the stratigraphic columns (Plate B-2) while reading the short descriptions of the formations which follow.



## Marine Formations

Sediments deposited under marine conditions include the Vaqueros, Rincon, Topanga, Modelo, and "Santa Margarita" formations. The Vaqueros formation of lower Miocene age consists of 100 to 1,800 feet of gray to brown marine sandstone and shale. The Vaqueros formation has been mapped by some geologists in the southwestern part of the Santa Monica Mountains where it consists of black calcareous shale and minor sandstone beds, but it is included with the Topanga formation on the geologic map of this report because of the extreme geologic complexity.

The Rincon formation consists of over 2,000 feet of dark gray to brown concretionary shale and is exposed only north of the Santa Clara River.

The Topanga formation is mapped only in the Santa Monica Mountains and Conejo Valley area. It is possibly the equivalent of the Rincon formation and the Vaqueros. Vaqueros fossils are found near the ocean south of Boney Mountain, but the beds are included in the Topanga formation because of the complexity of the area. The Topanga formation is mostly black or gray shale in the area southwest of Boney Mountain. It is composed of sandstone, conglomerate, and brown shale in the Conejo Valley area, and grades into sandstone and conglomerate in the easternmost portion of the area shown on the geologic map (Plate B-1C). The Topanga formation is closely associated with volcanic rocks. The sediments of the Topanga formation have an aggregate thickness of 6,000 to 9,000 feet, while the intercalated volcanics have a maximum aggregate thickness of about 13,000 feet. The Topanga formation is unconformably overlain by Modelo sandstone and shale.

The Modelo formation is variable in lithology but has been subdivided into sandstones and shales by Kew (1924). This subdivision has been followed and used on Plates B-1A, B-1B, and B-1C. Thickness of the Modelo formation varies from zero to 6,500 feet. The sandstones of the Modelo formation are generally

light grey to tan in color and are fine to medium grained, and they contain interbedded clay shales, and conglomerates. The shales of the Modelo formation generally consist of laminated diatomaceous and cherty shales and clay shales, with minor interbedded sandstones and conglomerates. Fish scales and foraminifera are usually abundant.

The "Santa Margarita" formation includes up to 2,000 feet of tan, silty, diatomaceous shales, and sandstones of uppermost Miocene age. Some of the rocks have been called the Pico formation by Kew and other names by other workers. The status of some of the sediments included in the "Santa Margarita" formation in this report is somewhat uncertain. This term has been adopted because of its predominant usage in the western portion of the county. The quotation marks are necessary, since lithology is not consistent and may not resemble that of the type locality.

Distinctive fossils of the Miocene marine formations are listed below:

"Santa Margarita" formation	<u>Delectopecten pedroanus</u>
Modelo formation	Foraminifera only
Topanga formation	<u>Turritella ocoyana</u> <u>Turritella boesei</u>
Rincon formation	Foraminifera only

For foraminifera in these formations, see Kleinpell (1938) and Hanna and Hertlein (1943).

#### Continental Sediments

Continental sediments of Miocene age include the Quatal formation in the Cuyama Valley area and the Mint Canyon formation in the Los Angeles County portion of the Santa Clara River drainage area. The Quatal formation consists of 500 feet of red gypsiferous clay, sand, and poorly cemented conglomerate underlain by 3,000 feet of red sandstone and poorly cemented conglomerate (Dibblee 1952). The Mint Canyon formation (Kew 1924) consists of 4,600 feet of lacustrine

and fluviatile sandstone, conglomerate, clay, and some marl. Fresh water molluscs, plant remains, and land vertebrate remains have been found in the Mint Canyon formation (Jahns, 1940).

### Volcanic Rocks

The volcanic rocks, mostly of Miocene age, associated with the Topanga formation include up to 13,000 feet of pyroclastics and basaltic flows. The pyroclastics include agglomerates, mud flows, and rhyolitic rocks. Andesitic and basaltic dikes, sills, and plugs intrude the flows and the associated Topanga sediments. Fossiliferous marine shales, sandstones, and conglomerates occur from place to place interbedded with the flows. The volcanics are faulted, highly fractured, and moderately folded.

### Hydrologic Properties

Most of the formations of the Miocene series are essentially nonwater bearing. Until 1953, the volcanics in the Conejo Valley and Tierra Rejada areas constituted the principal formation in the Miocene series which was significant as far as water supply is concerned. Further discussion of the water-bearing properties of the volcanics is included in the description of the ground water basins.

Present information indicates that none of the Miocene marine sediments are potential major ground water reservoirs. That is, few wells could be drilled which would yield large quantities of water from these rocks. Deep wells in the Miocene marine formations generally obtain brackish or salty water. The Mint Canyon formation contains permeable beds which are potential sources of supply. As far as is known, no irrigation wells obtained water from the Mint Canyon formation up to 1953. The Quatal formation, of Miocene age, in the Cuyama Valley area contains extremely permeable gravels. It is possible that



els yielding sufficient water for irrigation could be obtained if drilled in suitable locations. At present, only domestic wells are known to be supplied from this formation in Ventura County.

Surface water derived from areas of Miocene marine formations is generally a sodium-calcium-magnesium sulphate type containing from 400 to over 2,000 ppm total dissolved solids. The runoff from areas of Miocene continental beds is generally a calcium sulphate type with from 200 to over 1,500 ppm total dissolved solids.

### Pliocene Series

Formations of Pliocene age include the Pico, Saugus, and Morales formations, and the Ridge Basin Group.

The Pico formation consists of marine gray sandstone, blue gray shale, and lenticular conglomerate. These materials weather to a dull brown silty clay. Landslides are common in areas of outcrop. The Pico formation is unconformable with underlying and overlying formations in the Las Posas area but elsewhere is generally conformable. It varies in thickness from 12,000 feet in the Ventura area to zero in the Las Posas area. In the Ventura area, the Pico, Modelo, and Santa Barbara formations are conformable and interfinger. The Pico-Saugus contact in the Saugus-Castaic area in Los Angeles County transgresses time so that the lower part of the Saugus formation, near the town of Saugus, is the age equivalent of the upper portion of the Pico formation to the west. Typical fossils found in the Pico formation include Turritella cooperi, Pecten healyi, and Chione rnanadoensis.

The Saugus formation consists of up to 2,500 feet of non-marine brown sand, slightly cemented gravel, and gray or tan clay. Kew (1924) originally included the San Pedro and portions of the Santa Barbara formation as described in this report in the Saugus formation, but it is limited here to the eastern end of the Santa Clara River Valley in Los Angeles County. Vertebrate fossils

collected by W. H. Corey and identified by Chester Stock indicate that the Saugus formation in the Castiac-Saugus area is of upper and middle Pliocene age (verbal communication from W. H. Corey, April, 1953).

The Ridge Basin group of sediments is located between the San Andreas and San Gabriel faults south of Quail Lake, largely in Los Angeles County. This group consists of up to 18,000 feet of continental shale, sandstone, and conglomerate (Eaton 1939, Crowell 1950, August 1952, and Dehlinger 1952). Fresh water fish, vertebrate, and plant remains indicating Pliocene age are found in the Ridge Basin group (Axelrod 1950 and Crowell August, 1952).

The continental Morales formation is located in the northwest portion of Ventura County to the east and north of the Cuyama River. It consists of about 4,000 feet of gray to buff gravels and sands (Dibblee 1952).

#### Hydrologic Characteristics

The Pico formation is generally nonwater-bearing or yields salty water to wells. Some water wells in the Los Angeles County portion of the Santa Clara River drainage area probably obtain water from the permeable sands and gravels of the Saugus formation. A few water wells were observed which penetrate the Ridge Basin group in Hungry Valley and Peace Valley, upper tributaries of Piru Creek near U. S. Highway 99. A few irrigation wells are drilled into the Morales formation in Santa Barbara County. Both the Morales formation and the Ridge Basin group are possible potential ground water reservoirs. However, low rain-fall in these areas would probably result in limited replenishment of the formations after the ground water was depleted by pumping.

Surface water from the Pliocene formations is generally a sodium sulphate type with from about 400 to over 2,000 ppm total dissolved solids.

#### Lower Pleistocene Series

Sediments of the lower Pleistocene series comprise some of the most

important water-bearing formations in Ventura County. These include the Santa Barbara and San Pedro formations.

### Santa Barbara Formation

The Santa Barbara formation is of lowermost Pleistocene and uppermost Pliocene age (Bailey 1935). It had been previously included in the Pico formation by Kew (1924). It has been called upper Pico by Cartwright (1928), Driver (1928), and Waterfall (1929). The thickness and lithology of the Santa Barbara formation varies considerably from about 4,000 feet of mudstone, shale, and minor sandstone beds near the City of Ventura to about 1,000 feet of sand, gravel, and minor clay in the Tapo Canyon area and 800 feet of sand and clay in the southern part of the Oxnard Plain. Most of the clays and shales are blue in color when fresh, and contain plant remains and distinctive foraminiferal faunas. The slightly cemented buff colored gravels and sands on Oak Ridge referred to in this report as the Grimes Canyon member of the Santa Barbara formation extend southwestward under the Las Posas area and into the Pleasant Valley area, where they become mostly fine to medium sand. Typical fossils found in the Santa Barbara formation are listed below:

Vertebrates (Bailey 1935)

Equus cf. occidentalis

Invertebrates (Bailey 1935)

Pecten caurinus

Pecten bellus

Foraminifera (Natland 1952)

Cassidulina limbata

The foraminifera found in the Santa Barbara formation in the Hall Canyon area indicate deposition at depths of 125 to 900 feet below sea level, while the lithology of the Grimes Canyon member near Grimes Canyon indicates beach or



littoral deposition. The lithology and fossils indicate that the present area of the Santa Clara River Valley was under fairly deep water during deposition of sediments which comprise the Santa Barbara formation. A fluctuating shoreline extended from near the Santa Monica Mountains through Moorpark and eastward through the Tapo Canyon area. The northward extension of the shoreline is now concealed by structure or destroyed by erosion.

### San Pedro Formation

The San Pedro formation is of lower Pleistocene age. North of the Santa Clara River, it interfingers with the underlying Santa Barbara formation. South of the Santa Clara River, it is generally unconformable on the Santa Barbara formation. In the Oxnard Plain-Pleasant Valley area, the available oil well logs indicate a conformable contact. The San Pedro formation consists of up to 4,000 feet of marine and continental gravel, sand, and clay. North of the Santa Clara River, the San Pedro formation consists of extremely lenticular beds with many scour and fill features. The base of the San Pedro in this area contains abundant marine fossils, but from near the middle of the formation to the top, marine fossils are rare except near the City of Ventura and the Ventura River. An oil well drilled through part of the San Pedro formation near the mouth of Aliso Canyon encountered mostly blue-green clay with abundant wood fragments and plant remains, indicating fresh water swamp deposits. A prominent sand and gravel zone up to 300 feet in thickness containing marine fossils on the south side of Oak Ridge and beneath the Las Posas area is called the Fox Canyon member in this report. The Fox Canyon member can be traced on the surface and in water and oil well logs in the Las Posas area and is found at or near the base of the San Pedro formation. The Fox Canyon member extends into Pleasant Valley and the Oxnard Plain, but available well logs indicate that it is probably not as homogeneous there as it is in the Las Posas area.

During deposition of the San Pedro formation the Oxnard Plain was mostly submerged to depths of about 125 feet and was being filled by deposition from the ancient Santa Clara River. The Santa Clara River Valley itself was subsiding so that the thickness of sediments is now greater there than anywhere else in Ventura County. As the basin filled with sediments, the shoreline moved westward, and some of the San Pedro formation is, therefore, of continental origin. As a result, nearly all the San Pedro formation exposed near the Ventura River contains marine fossils, but only the base of the formation contains marine fossils just east of Santa Paula.

Nearly all the San Pedro formation in the Las Posas and Oxnard Plain areas was deposited in shallow water, probably partially in lagoons.

Typical fossils in the San Pedro formation are listed below:

Vertebrates (Bailey 1943)

Equus cf. occidentalis  
Chendytes lawi

Invertebrates (Bailey 1935)

Crepidula princeps  
Cancellaria tritonidea  
Cantharus fortis  
Pecten Circularis

Foraminifera (Natland 1952)

Elphidium hannai  
Rotalia becarrii

Some of the deeper sediments deposited in Simi Valley and Ojai Valley may be of lower Pleistocene age but are described herein with the upper Pleistocene Series.

#### Hydrologic Properties

Ground water occurs in sands and gravels of the Santa Barbara and San

Pedro formations. The Santa Barbara formation probably contains water of poor quality in the Santa Clara River area and portions of the Oxnard Plain-Pleasant Valley area as is indicated by electric logs of a few oil wells. The Grimes Canyon member contains fresh water of good quality in the Las Posas area and in the Pleasant Valley area. At the time of this investigation, only a few wells were obtaining water from the Grimes Canyon member or other sands of the Santa Barbara formation alone. A few other wells obtained water from the Santa Barbara as well as the overlying San Pedro formation.

The San Pedro formation yields water to wells in the Santa Clara River Valley and in the Las Posas, Oxnard Plain, and Pleasant Valley areas. As far as is now known, all water in the San Pedro gravels and sands is of good quality except that below about 2,000 feet in the Santa Clara River area, where a few electric logs indicate that the water may be slightly brackish.

Surface runoff from the Santa Barbara and San Pedro formations is generally of fair quality.

#### Upper Pleistocene and Recent Series

Sediments of upper Pleistocene age include most of the gravels, sands, and clays younger than the San Pedro formation. In general, they are all undisturbed or only gently folded in contrast to the San Pedro and older formations.

The upper Pleistocene series in the Oxnard Plain-Pleasant Valley area extends from the top of the San Pedro formation to within about 20 to 50 feet of the surface. It consists of up to 500 feet of interbedded marine blue clay and sand, alluvial silt, and stream deposited sand and gravel. The principal aquifer on the Oxnard Plain is a stream deposited gravel of upper Pleistocene age which is called the Oxnard aquifer in this report. In the Pleasant Valley area, the upper Pleistocene series contains lenticular gravels which yield water to wells. From available well log data, the base of the upper Pleistocene series



appears to lie unconformably on the San Pedro formation in Pleasant Valley and in parts of the Oxnard Plain.

The alluvium in Simi and Ojai Valleys is probably largely of upper and lower Pleistocene age, approximately the upper 50 feet being Recent. Most of the alluvium in the Santa Clara River Valley is also Pleistocene, and the total thickness of alluvium in the river bottom ranges from five or six feet at Blue Cut to over 200 feet elsewhere. Most of the terrace deposits in Ventura County are probably upper Pleistocene.

Recent Alluvium is quite thin over most of Ventura County, probably no more than 60 or 70 feet thick. It consists of sand, gravel, and clay. Most water wells obtain water from materials underlying the Recent alluvium except in those areas where the water table is high.

Both upper Pleistocene and Recent sediments are more fully discussed under the description of ground water basins.

## CHAPTER B-IV. STRUCTURE

The purpose of this chapter is to discuss the geologic structure of Ventura County, placing particular emphasis on those features which affect the occurrence and movement of ground water.

Ventura County is located in two regions of fairly distinct structural characteristics which coincide with the geomorphic provinces mentioned in Chapter B-II. The portion of the County north of the Santa Ynez fault (see Plate 10) is in the southern Coast Range province, and the portion south of this fault is generally included in the Transverse Range province. At the extreme northeast corner of Ventura County, the Sierra Nevada and Mojave Desert provinces meet both the Coast Range and Transverse Range provinces near Lebec.

Many major structural features in Ventura County trend east-west, although considerable variation in direction exists. Principal structural features of Ventura County and adjacent areas are shown on Plate 10. Plates B-1A, B-1B and B-1C show additional details of structure of the southern portion of the County. Geologic cross-sections are also included on these latter plates to illustrate structural features.

### Faults

Faults in the Ventura County region may be divided into northwest-southeast trending, northeast-southwest trending, and east-west trending faults. Some faults have been displaced horizontally and some vertically, while both components of movement have occurred on others. Aside from the major or prominent faults shown on the geologic maps, there are minor faults and fractures too numerous to indicate. Nearly all faults are actually zones of faulting, the width of the zone generally being greatest on the larger faults. Relative directions of movement along the faults, where known, are shown on the geologic maps.

### Northwest-Southeast Trending Faults

Major faults trending in a northwest-southeast direction include the San Andreas, Nacimiento, Pine Mountain, Hot Springs, San Gabriel, and Santa Susana faults. The San Andreas fault is well known and is the longest fault in California. Horizontal or more correctly right lateral movement has been predominant, with over 300 miles displacement possibly occurring since Jurassic time suggested by Hill and Dibblee (1953). The Nacimiento fault extends into Ventura County near the Cuyama River. The Hot Springs fault, which is located southwest of Lockwood Valley, may be an extension of the Nacimiento fault, the two having been displaced by the Big Pine fault. The San Gabriel fault is another major fault of California. Like the San Andreas fault, the predominant movement has been horizontal, and Crowell (Oct. 1952) has presented evidence for about 25 miles horizontal displacement along the fault since Miocene time. The Santa Susana fault, in the Santa Susana Mountains of Ventura and Los Angeles Counties, is a thrust fault which dips to the north and appears to override the east end of the Garlock Ridge fault (Herron 1952 and Sheller and Bien 1947).

### Northeast-Southwest Trending Faults

The most prominent northeast-southwest trending faults are the Big Pine and Sycamore Canyon faults. According to Hill and Dibblee (1953), the Big Pine fault is probably an extension of the Garlock fault (not shown), the two having been displaced by movement on the San Andreas fault. Hill and Dibblee report a possible horizontal displacement on the Big Pine fault of 14 miles. The Sycamore Canyon fault and associated faults in the Santa Monica Mountains are about 15 miles long, and as far as can be determined have had mostly a vertical component movement.

It is possible that a major northeast-southwest trending fault exists along the southeast edge of Pleasant Valley, but no evidence could be found that



such a fault affects water-bearing materials, and it has not been shown on the geologic maps.

#### East-West Trending Faults

Most of the remaining major faults in Ventura County are essentially east-west trending. The northernmost of these faults will be discussed first, and those on the south side of the county last.

The Pine Mountain fault is a north dipping reverse fault, and is apparently a branch fault connecting the Big Pine and Hot Springs faults. The Tule Creek fault, although more than 20 miles long, is apparently not directly connected with other major faults. The Santa Ynez fault is another of the major California faults which have probably had both horizontal and vertical components of movement.

The Santa Ana fault, which crosses the Ventura River drainage area, has had fairly recent movement, and probably has been an important factor in the accumulation of the alluvial fill in Ojai Valley.

The San Cayetano fault is a north dipping reverse or thrust fault with a known low dip of about 20 degrees near Fillmore, and of about 60 degrees north of Santa Paula. The San Cayetano fault actually consists of two or more branches often with soft, easily deformed sediments between them (Sheller and Bien 1947). Nonwater-bearing formations have been thrust over the San Pedro formation along the San Cayetano fault in the area northeast of Fillmore. North of Santa Paula, Eocene sediments have been thrust over Pliocene sediments as shown on Section C-1, Plate B-1B.

The Oak Ridge fault extends along the south edge of the Santa Clara River Valley from Saticoy to a point about two miles southeast of Piru, where it turns southward into Oak Ridge and is cut off by the Santa Susana fault. The Saticoy fault may be a westward extension of the Oak Ridge fault or a branch of it. The Oak Ridge fault has been penetrated by several oil wells drilled on Oak

edge, and it has been found that the fault dips southward about 60 degrees. Older formations have been thrust up from the south over younger San Pedro sediments (see Section C-C', Plate B-1B).

Evidence for the location of the Saticoy fault shown on Plate B-1B was found in logs of oil wells and in differences in water level elevation across it. It is not certain what happens to this fault at depth, but it does appear to die out westward and cannot be detected in well logs north of Montalvo or along the beach south of Ventura. The south side of the Saticoy fault has been uplifted relative to the north side.

The Simi-Santa Rosa fault system consists of several branches and extensions. The north side of this fault system has been generally uplifted relative to the south and has apparently been one of the causes for the accumulation of the thick alluvium in Simi Valley. East of Simi Valley the relative direction is reversed, with the south side being uplifted, suggesting a hinge or scissors type fault.

It could not be determined during this investigation whether either the Springville fault zone or the Camarillo fault are extensions of the Simi-Santa Rosa fault system. The Springville fault zone is located on the south side of the Camarillo Hills and consists of at least two parallel faults, portions of which are well exposed on the surface. It is possible that the fault zone continues eastward south of Somis, but outcrops and well log data are not available to show this. This fault zone does not appear to affect the Oxnard aquifer in the Oxnard Plain although it does affect the San Pedro and older formations, at least near the Camarillo Hills. The Springville fault zone dips steeply to the north with the north side being uplifted relative to the south.

The Camarillo fault extends along the south side of a low hill near the town of Camarillo and curves northeastward toward Santa Rosa Valley. Evidence for this fault is found in well logs, physiographic features and water level

data. The fault is probably nearly vertical and the north side is uplifted. The fault appears to fade out eastward and cannot be detected beyond the Camarillo Airport.

#### Faults of Hydrologic Significance

The major faults in Ventura County which are known to have a barrier effect on ground water are the Saticoy and Springville faults and a portion of the Camarillo fault. Some of the other major faults described above with accompanying folding generally affect ground water indirectly by deformation of the water-bearing materials. This deformation in some cases has resulted in changes of cross-section area of water-bearing formations, and in exposure and erosion of portions of the formations so that they can be recharged by surface waters.

Some of the faults of Ventura County may also be avenues of escape for deeper waters of poor quality. Faults which may be in this category include the Hot Springs and Santa Ynez and possibly the San Cayetano and Oak Ridge faults. Evidence for escape of deeper waters appears in the analyses of spring water, and in some cases in analyses of ground water in alluvium near the faults.

The Saticoy fault affects the San Pedro formation and possibly the overlying alluvium. It appears to act as a partial barrier to flow of ground water with a water level differential across it of up to 100 feet (see Plates 14B, 15B, and 16B). The barrier effect of the fault seems to be most pronounced near the town of Saticoy. Its effect on ground water in the area of the Santa Clara River bed is not known due to lack of well control. The fault also appears to die out or become less effective so that no prominent differentials in water levels can be detected across the fault two or three miles westward of Saticoy. The barrier portion of the Saticoy fault also results in the deflection of a part of the underflow from Santa Paula Basin westward into Mound Basin, the remainder flowing through or over the fault into Oxnard Forebay Basin.



The Springville fault zone has displaced the San Pedro and underlying formations. This displacement and the reduction of permeability caused by movement as shown on surface exposures of the fault has caused a barrier to southward movement of ground water from beneath the Camarillo Hills into Pleasant Valley Basin. The barrier effect is evidenced by up to 60 feet water level differential across the fault in aquifers of the San Pedro and Santa Barbara formations. It is probable that the Springville fault zone has not affected alluvium in the Central Plain area.

Study of well logs indicates that the Camarillo fault displaces the San Pedro formation and probably some of the alluvium near the town of Camarillo. Ground water contours generally do not indicate that this fault acts as a barrier to flow of ground water in the San Pedro formation. Field observations indicate, however, that local drawdown of pumping wells does not extend across the fault. Water levels in the lenticular aquifers of the alluvium do appear to be higher on the north side of this fault, suggesting that it may act as a barrier to the southward movement of ground water in the alluvium.

### Folds

All rocks and sediments in Ventura County, except those most recently deposited, have been folded. Most of the folds, like the faults, trend in an east-west direction. In general, there are three prominent anticlinal areas which usually consist of several smaller folds. These are the Topatopa Mountains near the Santa Ynez fault, Oak Ridge, and the Simi Hills south of Simi Valley. The Santa Monica Mountains in the Ventura County area are essentially a north dipping homocline. The principal areas which are essentially synclinal in structure are: the Cuyama drainage area northwest of the Big Pine fault, the area between and near the intersection of the San Andreas and San Gabriel faults which has been called the "Ridge Basin" in geologic literature, the Santa Clara River syn-

cline, and the area south of Oak Ridge.

Some of the folded formations in the high hills and mountains may form limited ground water basins under certain conditions, but since most of these structures are not explored by wells, they are not discussed further.

### Folds of Hydrologic Significance

The most significant folds from a ground water standpoint are the Santa Clara River syncline, the Montalvo anticline, and the series of folds in the synclinal area south of Oak Ridge, all of which affect water-bearing materials.

Santa Clara River Syncline. The Santa Clara River syncline extends from the ocean south of Ventura up the Santa Clara River into Los Angeles County. The origin of this syncline was closely related to movement of the Oak Ridge and San Cayetano faults, as well as the Ventura Avenue anticline (see Plates B-1 and B-1B). It is probable that the Santa Clara River syncline was initially folded without faulting, and faulting occurred later when the sides of the fold became fairly steep (Reed, 1933). Of interest here is the fact that the water-bearing San Pedro formation has been folded in the Santa Clara River syncline, resulting in erosion and exposure of the upturned edges so that ground water is now replenished by surface water. The north flank of the folded San Pedro formation is exposed from the ocean to a point about three miles east of Santa Paula and may be recharged by rainfall penetration and stream percolation. The south flank of the syncline may be partially eroded and covered by alluvium along the course of the Santa Clara River and partially covered by older formations which have been thrust up along the Oak Ridge fault.

Montalvo Anticline. The Montalvo anticline, which affects the San Pedro formation, extends from the ocean up the south side of the Santa Clara River, crosses the river near Montalvo, and continues eastward south of the Saticoy fault. The Montalvo anticline appears to be cut off by the Saticoy or Oak Ridge fault.

near the west end of Oak Ridge. This anticline is shown on the geologic map (Plate B-1B) as a single continuous fold, but may consist of two or more individual anticlines. The area in the vicinity of the anticline is complicated by minor faults and folds and it is difficult to determine details of the structure and their effect on the movement and occurrence of ground water. It seems clear that the Montalvo anticline has folded the San Pedro formation so that it has been eroded and covered by alluvial gravels in Oxnard Forebay Basin. As a result, some aquifers of the San Pedro formation are most likely in hydrologic continuity with ground water in the overlying alluvium.

Folds South of Oak Ridge. The folds in the area south of Oak Ridge in the Las Posas area (see Plate B-1C) affect the principal aquifers there. These folds result in the aquifers being exposed in certain areas where they can be recharged by surface waters and buried in other areas where water wells can be drilled into them. The upturned edges of the aquifers and in some cases the crests of anticlines serve as ground water storage reservoirs for the deeper portions of the aquifers. Change of storage probably occurs in the Fox Canyon aquifer in portions of the Long Canyon, Moorpark, and Camarillo anticlines. In the deeper synclinal areas ground water within the aquifers is usually confined by underlying silts and clays.



## CHAPTER B-V. GEOLOGIC HISTORY

The geologic history of Ventura County has been very complex. Portions of the area have been repeatedly covered by the sea and then uplifted, while other portions have been below sea level nearly all the time. A few areas have been generally above sea level so that sediments were not deposited on them. The Tertiary history of Ventura County has been closely related with the history of a larger region which includes much of Santa Barbara County, the Channel Islands, and a portion of Los Angeles County, and is designated Ventura Basin in this report. The term basin as used here means geologic basin. The northern portion of this large area has been called the Santa Barbara embayment. The Channel Islands and parts of the Santa Monica Mountains have been called Anacapia by Reed (1933) and Reed and Hollister (1936), but for purposes of discussion the two areas are discussed here as one. Ventura Basin during most of Tertiary time was a broad east-west trending downfolded belt, with gentle uplifting occurring to the north and south. History of events prior to Tertiary time is obscure due to lack of exposures of pre-Tertiary rocks. The axis or deepest portion of the basin where the thickest sediments are found varied during Tertiary time. During Eocene time the axis was located in the northern portion of the County. In Oligocene time, the axis appears to have been along the central part of the County, and in Miocene time the major axis appears to have been in the south portion in the Santa Monica Mountains, with perhaps a secondary basin existing in the central portion of the County. During Pliocene and Pleistocene time the axis near the central part of the County remained the most prominent. It appears to have migrated slowly southward, so that at the present time the deepest part of Ventura Basin coincides with the axis of the Santa Clara River syncline (see Plate B-1B).

Since Eocene time, much of the northern portion of Ventura County has been eroded. The eroded area has grown larger as the axis moved southward and the northerly areas were uplifted. In the Santa Monica Mountains great thick-

masses of volcanics and marine sediments accumulated during Miocene time, but the area was apparently uplifted in the Pliocene since no Pliocene sediments have been found there. These flexures in the earth's crust were accompanied by faulting and gentle folding of the sediments. In middle Pleistocene time, however, folding and faulting was accelerated during the Santa Barbaran orogeny. This middle Pleistocene orogeny resulted in overturning of folds, subsequent breaking of the folds into thrust fault, (Reed 1933), and the development of geologic features essentially as they are today. Evidence is available that thrusting occurred first from the south and later from the north (Herron 1953). After the middle Pleistocene orogeny the land was eroded into gently rounded hills and mountains, while upper Pleistocene deposits were still being deposited in the valleys. During upper Pleistocene time, however, fluctuations in sea level, possibly related to world wide glaciation, caused changes in base level of the streams. During periods of low sea level, renewed erosion of portions of the valley fills and the rolling uplands occurred. As the water level rose after the last glacial period, streams deposited their loads and filled the valleys once more.

The latest events appear to include the following: (1) continued activity along certain faults; (2) continued folding such as the folded terraces of the Ventura River drainage area (Putnam 1942); (3) renewed downcutting and downward erosion of streams, which may be due to a combination of man's alternation of natural conditions and climatic changes.

The events since the mid-Pleistocene orogeny have had considerable effect on the development of the submarine canyons. It is not known if the canyons existed before that period. Whether they did or not, however, it is possible that the load of sediments carried by the ancient Santa Clara River may have been of considerable importance in present development of the canyons. During the upper Pleistocene, the Santa Clara River continually shifted its course so that at various times all parts of the Oxnard Plain were covered, and the river probably

discharged at various times into the ocean at all points along the coast from the Santa Monica Mountains to its present position. Discharge of sediments onto the ocean floor in the area of the steep east-west submarine scarp south of the Coastal Plain may have resulted in submarine landslides, mudflows, and turbidity currents, which once started would continue from time to time as river sediments and transported beach sediments were dumped into the head of the canyons. The ocean floor west of Oxnard has a gentle slope, and it is probable that canyons have not been started there due to low velocities of turbidity currents and other transporting agents. It would appear that the submarine area west of Oxnard has been aggrading while the area to the south of Oxnard has been undergoing degradation and dissection which has been at least in part responsible for the formation of the submarine canyons.



## CHAPTER B-VI. GROUND WATER STORAGE AND SUBSURFACE FLOW

The purpose of this chapter is to explain the procedures used to determine quantitative estimates of ground water storage and subsurface flow.

### Ground Water Storage

Ground water is stored within the interstices of sediments and in cracks or fractures of solid rocks. The changes in ground water storage occurring over selected periods of study were estimated for the more important ground water basins within the County. Results of these studies are discussed in Chapter I. In general, the procedures of estimation required first a determination of the change in the volume of saturated sediments that occurred over a selected study period and second an estimate of the percentage of this volume that contained extractable ground water. The first factor was obtained by computing the volume of sediments that lay between the water tables that existed at the start and close of the study period; the second factor from evaluating the average weighted specific yield of the sediments between water tables from available well logs. Storage changes over the periods of study were computed by multiplying changes in volume of saturated sediments by average weighted specific yield.

### Specific Yield

The specific yield of a sedimentary deposit is the ratio of the volume of water which it will yield by gravity after being saturated, to its own volume, customarily expressed in per cent. In its South Coastal Basin Investigation, the Division of Water Resources conducted extensive field and laboratory investigations for the purpose of assigning specific yield values to various types of material appearing in well logs. These procedures are described in Bulletin No. 5 "Geology and Ground Water Storage Capacity of Valley Fill" (Division of Water Resources, 1934). With slight variations, the values determined in this earlier

work and Bulletin 46 "Ventura County Investigation" were adopted for compiling the change of storage estimates presented here.

The task of assigning specific yield values to the sediments appearing in logs was simplified by dividing all basin sediments into eight general categories. These included soil, clay, clay-sand, clay-gravel, tight sand, sand tight gravel, and gravel. Sand, gravel, and clay, which constitute the bulk of the basin sediments, were generally found to be well differentiated on the driller's logs. Combinations of these materials, however, were frequently described by such unique terms as "ooze", "muck", "cement", etc. Materials so described were placed, based on the judgment of a geologist, into one of the above eight categories. Table B-1 indicates specific yield values assigned to the general categories. In certain instances, these values were altered slightly whenever field observations indicated the advisability of changes.

TABLE B-1

SPECIFIC YIELDS OF SEDIMENTS

Material	: Specific Yield (Per Cent)
Soil, including silty clay	3
Clay, including adobe and hard pan	0
Clayey sand, including sandy silt	5
Clayey gravel	7
Sand	25
Tight sand, including cemented sand	18
Gravel, including gravel and sand	21
Tight gravel, including cemented gravel	14

Selection of Increments

Each ground water basin was subdivided into smaller areas. Units of 100 acres were adopted in the larger basins where well logs were abundant and larger areas were used in basins for which little data were available. The sediments underlying each such subarea were separated at selected depth intervals. In this manner, each basin was divided into zones, the storage capacity of which

could be conveniently estimated. The change in ground water storage for each entire basin was then computed as the sum of the changes occurring within the zones.

### Subsurface Flow

Two methods were used to determine subsurface flow. These were the slope-area method and the rising water method.

#### Slope-Area Method

The slope-area method is based on the commonly used form of Darcy's law,  $Q = PAI$ , where  $Q$  equals subsurface flow in gallons per day passing through the cross-sectional area  $A$  in square feet;  $P$  is permeability in gallons per day per square foot; and  $I$  is slope of water table at the cross-section in feet per foot. This method is fairly reliable in cases where cross-sectional area can be determined from well logs, permeability can be estimated by pump tests, and the ground water slope can be accurately measured.

#### Rising Water Method

The rising water method of computing subsurface flow is applicable where rising water occurs perennially and where the cross-sectional area of saturated sediments is unknown. The method has been mentioned by Tolman (1937) and a variation of the method was used by Kimble (1936). The rising water method is also based on Darcy's law.

Let  $Q_t$  equal total subsurface flow past a cross-section of the valley all at the point of zero rising water,  $X$ , upstream from the point of maximum rising water,  $Y$  (see diagram below). Let  $Q_u$  be the subsurface flow at the point of maximum rising water and  $Q_r$  the maximum rising water at any time. Assuming that little or no water is lost by diversion or evapo-transpiration between  $X$  and



Y, and that steady flow conditions exist it follows that:

$$Q_t = Q_u + Q_r$$

At point X the total subsurface flow may be expressed as

$$Q_t = PAI$$

and

$$Q_u + Q_r = (PA) I$$

where

P = permeability

A = cross-sectional area

I = slope of water table at point X, as measured in wells just upstream from X.

It is assumed that:

1. Flow is horizontal.
2. The materials are essentially homogeneous.
3. The change in cross-sectional area due to change in water levels is negligible.
4. Permeability is constant throughout the section.

Under these assumptions, the variations in  $Q_r$  must be dependent only upon I.

Two periods  $t_1$  and  $t_2$  may be taken so that

$$Q_u + Q_{r1} = (PA)I_1 \quad (1)$$

and

$$Q_u + Q_{r2} = (PA)I_2 \quad (2)$$

Subsurface flow or  $Q_u$  is nearly constant as long as any rising water occurs, since I at Y is essentially determined by the surface of the stream.

Dividing (1) by (2):

$$\frac{Q_u + Q_{r1}}{Q_u + Q_{r2}} = \frac{PA(I_1)}{PA(I_2)}$$

and solving for  $Q_u$

$$Q_u = \frac{I_1(Q_{r2}) - I_2(Q_{r1})}{I_2 - I_1}$$



In order to complete the hydrologic studies of the Santa Clara River basins it was necessary to estimate the decrease in subsurface flow when water level of the basins were drawn down and rising water stopped. In order to do this the logarithm of rising water plus previously estimated subsurface flow was plotted against basin storage depletion and found to be nearly a straight line. This line was then projected past the point where zero rising water occurred and the projected line was used to estimate subsurface flow for conditions of zero rising water. This method of estimating subsurface flow with zero rising water is based on the assumption that the storage depletion of the basin and the slope of the water table upstream from the area where rising water occurred are related, and that the change of wetted cross-sectional area due to change in ground water level is negligible. In general, it was found that these factors were related during the period of record, so that the assumption appears to be valid.

#### Permeability

Pump tests to determine permeability were conducted where possible. These data are summarized in Table B-2. Permeability was computed using non-equilibrium methods as outlined in the Division of Water Resources "Draft of Report of Referee" No. 506806, of the West Coast Basin, February, 1952. Slight variations in methods as suggested by Wenzel (1942) and Jacobs and Cooper (1946) were used where necessary. In general, the recovery and the drawdown methods were used depending on conditions. These methods depend on time-rate of recovery after pumping stops or time-rate of drawdown during pumping. The last column of Table B-2 indicates relative reliability of results due to conditions at the time of the tests.



TABLE B-2

## SUMMARY OF PERMEABILITY PUMP TESTS

Well	Test Method	Basin and Aquifer	Transmissibility : : Gallons per Day : : per Foot	Thickness : : of Aquifer : : from : : Well Log : Square Foot	Permeability : : Gallons per : : Day per : : Square Foot	Storage : : Coefficient : : to 0.25	Conditions : : of Test
1N/21W-14B1 Camarillo Hospital	Drawdown	Pleasant Valley - Older alluvium, San Pedro fm., and volcanics	54,800	280	220	.043	Poor
1N/22W-17C1 U.S. Navy	Recovery	Oxnard Plain - Oxnard aquifer	198,000	100	1,980	---	Good
1N/22W-17C2 U.S. Navy	Recovery	Oxnard Plain - Oxnard aquifer	264,000	100	2,640	---	Good
2N/19W-15B2	Drawdown	Tierra Rejada - volcanics	120,000	600	200	.096	Fair
2N/20W- 4F1 Las Posas Orchards	Recovery	East Las Posas - Fox Canyon aquifer	177,300	426	416	---	Good
2N/23W-14M1 Ventura City	Drawdown	Mound - San Pedro fm.	220,000	280	780	.00037	Poor
3N/23W- 8G Ventura City	Drawdown	Upper Ventura River - alluvium	36,000 (average)	20	1,800	.00056 to 0.25	Fair (Composite of 4 wells)
4N/19W-33D4 State Fish Hatchery	Recovery	Piru-Fillmore San Pedro fm.	1,220,000	338	3,600	---	Poor

## CHAPTER B-VII. DESCRIPTION OF GROUND WATER BASINS

Seventeen ground water basins delineated in Ventura County in the course of this investigation are discussed in the following paragraphs. The boundaries of these basins are shown on Plate 11. In addition, there is discussed herein an additional basin known as Eastern Basin, which is located in Los Angeles County but which affects the regimen of flow in the Santa Clara River in Ventura County. Several further ground water bodies which presently yield but little water, are discussed under the name of the locality in which they occur, namely, Malibu hydrologic unit, Rincon subunit and Rincon Creek drainage area, Cuyama River drainage area, and upper portions of Piru Creek drainage.

The boundaries of ground water basins in most instances conform with geologic features such as contacts between permeable and impermeable formations, fault zones of low permeability, or changes in subsurface lithology which affect movement or mode of occurrence of ground water. These boundaries were established from available data, including well logs, areal geology, and hydrologic observations.

In general, there are three types of ground water basins in the County. These include (1) basins composed of unconsolidated sediments or alluvium, (2) volcanic rock basins, and (3) basins composed of consolidated rocks. The first type of basin comprising unconsolidated sediments or alluvium has been further divided into two sub-types: the simple type basin in which ground water occurs in a single unconfined body, and the complex basin in which ground water occurs in more than one aquifer. The characteristics of these types of basins are summarized in Table B-3.

TABLE B-3

## CHARACTERISTICS OF TYPES OF GROUND WATER BASINS

Type of basin	Basin or subunit	Type of wells and general characteristics	Nature of basin fill	Water table conditions at wells
Unconsolidated Sedimentary or Alluvial Basins	Simple Ojai Upper Ojai Ventura River Basins Simi Piru Fillmore Santa Paula Oxnard Forebay Miscellaneous Areas	Irrigation mainly. Many wells, yields generally high.	Lithologically heterogen- eous, but permeable zones interconnected to form one water body.	Generally unconfined.
	Complex Mound Oxnard Plain Pleasant Valley East and West Las Posas Santa Rosa Miscellaneous Areas	Irrigation mainly. Many wells, yields generally high. Com- monly show pressure effects.	Usually two or more aqui- fers, frequently in well defined depth zones. Some free ground water areas.	Frequently confined. May be part- ly uncon- fined or both.
Volcanic Rock Basins	Tierra Rejada Parts of Conejo Basin Parts of Malibu Hydro- logic Unit	Domestic and limited irrigation. Wells numerous with moder- ate yields.	Basin structure may be complex. Water occurs in fractures. Highly fractured zones produce more water.	Generally unconfined.



TABLE B-3 (Continued)

CHARACTERISTICS OF TYPES OF GROUND WATER BASINS

Type of basin	Basin or subunit	Type of wells and general characteristics	Nature of basin fill	Water table conditions at wells
Consolidated Rock Basins	Parts of Ventura River Subunits Simi Subunit (Hill areas) Parts of Conejo Basin Parts of Malibu Hydro- logic Unit Miscellaneous Areas	Domestic, stock watering, and limited irrigation. Few wells-yields gener- ally low.	Structure may be extremely complex. Water occurs in fractures and/or inter- stices.	Confined, unconfined, or both.

Ground water basins of most economic importance in Ventura County are those possessing a combination of sufficient replenishment, sufficient storage volume to regulate the water supply, and materials which will readily yield water to wells. In general, the unconsolidated sedimentary basins are of greatest economic significance.

## Ground Water Basins Within Ventura Hydrologic Unit

Ground water basins in the Ventura Hydrologic Unit include Upper Ojai, Ojai, Upper Ventura River, and Lower Ventura River Basins. Locations of the basins are shown on Plate 11, and physical characteristics are summarized in Table 9. Other portions of the Ventura Hydrologic Unit contain relatively small areas of shallow water-bearing materials. Water wells in such areas are usually shallow and have low yields. Some wells in these areas obtain water from the fractures and pervious zones within consolidated Tertiary sediments.

Plate B-1A (Areal Geology) depicts the details of structure and extent of formations within this unit.

### Upper Ojai Basin

This basin lies within the Upper Ojai Subunit. It comprises a surface area of about 1,950 acres situated in the northeasterly portion of Ventura Hydrologic Unit. Elevations vary from 1,200 feet to 1,600 feet above sea level. Surface waters drain westerly through Lion Canyon into San Antonio Creek and easterly along Sisar Creek to Santa Paula Creek.

Geology. The water-bearing materials comprising the ground water basin include Recent and Pleistocene stream deposited gravel, sand and clay, and to a limited extent deeply weathered older formations. The alluvial materials are known to exceed 300 feet in thickness at a well near Sisar Creek, though their average thickness is estimated to be about 60 feet. The Tertiary sediments that flank the basin consist of consolidated marine and continental sandstone, conglomerate, and shale, and contain water of poor quality in some areas. These Tertiary sediments include the Pico, "Santa Margarita", Modelo, Rincon, Vaqueros, and Sespe formations, all of which are folded and faulted.



Occurrence of Ground Water. The alluvium comprises the principal source of ground water. In general, ground water is unconfined and surface waters percolate relatively freely to the water table. Ground water also occurs in fractures in the consolidated Tertiary sediments which flank and underlie the alluvium. There are a few springs supplied from such fractures in the rocks. Most wells in the basin penetrate the alluvium and bottom in the older rocks. The alluvium underlying much of the basin drains rapidly to Lion Canyon and Sisar Creek and consequently only a few feet of water accumulate above the base of these materials.

Movement of Ground Water. The ground water in Upper Ojai Basin divides, part flowing eastward to Sisar Creek and the remainder flowing westward into Lion Canyon. The location of the ground water divide and the directions of movement are depicted by contours on Plate 16-A.

Replenishment and Depletion of Ground Water. The principal sources of ground water replenishment are deep penetration of precipitation, percolation of surface water in streams, and percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water is depleted by pumped extractions, consumptive use of phreatophytes, and drainage of springs into Sisar Creek and Lion Canyon.

Subsurface Inflow and Outflow. Consolidated Tertiary formations flank the alluvial deposits, preventing appreciable subsurface outflow to Ojai Basin. Springs exist near the base of the alluvium in both Sisar Creek and Lion Canyon, although this water leaves the basin as surface flow.

Ground Water Storage Capacity and Specific Yield. Alluvium in this basin is relatively shallow, with an average estimated depth of about 60 feet. Water in these sediments drains rapidly to springs situated at lower elevations,

as indicated in the preceding paragraphs. Though no estimates were made, the usable storage capacity is believed to be small.

Yield of Wells. The yield of wells ranges from about 10 to 200 gallons per minute, with an estimated average yield of about 50 gallons per minute.

### Ojai Basin

This basin, with an areal extent of about 6,040 acres, lies in the northerly portion of the Ventura Hydrologic Unit and to the northwest of Upper Ojai Basin. Elevations vary from about 700 feet to over 1,200 feet above sea level. Surface waters within this basin drain to the southwest in San Antonio Creek toward the Ventura River.

Geology. Rock types of Ojai Basin consist of permeable stream deposits of Recent and Pleistocene age flanked and underlain by older consolidated sedimentary formations as shown on Geologic Sections E-E' and F-F' on Plate 12-A.

The alluvium consists chiefly of gravelly clay and gravel up to 700 feet in thickness. Boulders and pebbles in the gravel consist chiefly of sandstone or conglomerate derived from the surrounding drainage area. Well logs show less clay in the easterly end of the valley than in the vicinity of the City of Ojai. Only a few well logs are available in the area west of the city, but here the low yield of wells indicates that the clay content is probably high. Samples of the deeper alluvium obtained during the drilling of wells appeared to be strongly weathered. The alluvium of Recent age is composed of about 50 to 100 feet of sediments similar to those occurring in the underlying Pleistocene alluvium though usually less weathered. Distinction between the two formations is usually difficult.

The older Tertiary formations including the Modelo, Rincon, Vaqueros, Sespe, Coldwater, and Cozy Dell are usually consolidated or cemented, and may contain water of poor quality.

Ojai Valley is essentially a down-faulted and folded area, which has been filled with permeable stream deposits consisting of the Recent and Pleistocene alluvium. Surface exposures of the Pleistocene alluvium indicate that the beds dip from 10 to 30 degrees.

Occurrence of Ground Water. Ground water occurs within alluvial deposits and to some extent in fractures and interstices of the flanking Tertiary formations. Ground water is generally unconfined except in the southwestern portion of the basin where flowing wells during periods of high water level indicate local confined conditions. Percolation of surface water to the water table appears to be relatively unrestricted in the balance of the area.

Movement of Ground Water. Directions of ground water movement are shown by water level contours on Plates 14-A, 15-A, and 16-A. In general the movement is toward the south and west converging on San Antonio Creek near its outlet from Ojai Valley. During periods of low water levels (Plate 16-A) the water table slope is reversed in the southwest portion of the basin.

There are no known barriers to movement of ground water in this basin.

Replenishment and Depletion of Ground Water. Ojai Basin is replenished by percolation of surface water in stream channels, by water diverted from Matilija Dam into the Ojai spreading grounds, by deep penetration of precipitation and percolation of the unconsumed portion of water applied for irrigation, and to a slight extent by subsurface inflow from the surrounding Tertiary formations. The basin is depleted by pumped extractions, by consumptive use of phreatophytes, and by effluent discharge into San Antonio Creek.

Subsurface Inflow and Outflow. Ojai Basin is isolated from Upper Ojai Basin by nonwater-bearing Tertiary formations which prevent the movement of appreciable quantities of ground water between these basins. At the westerly end of



Ojai Valley near the outlet of San Antonio Creek, bedrock is exposed along the creek bottom. A short distance northeast of this outlet, nonwater-bearing sediments of the Sespe formation are exposed in a small hill. North of this hill there are a few deep wells in the valley floor which yield only small amounts of water although their logs indicate only sedimentary material. These observations suggest that at the westerly end of Ojai Valley, a relatively thin mantle of alluvium overlies essentially nonwater-bearing Sespe formation. Subsurface outflow from Ojai Valley to Ventura River Basin is therefore probably insignificant.

Ground Water Storage Capacity and Specific Yield. Specific yield and storage capacity of the water-bearing materials and changes in storage occurring over selected study periods were computed in the manner described in Chapter B-VI, and results are discussed in Chapter II. Total usable storage capacity of Ojai Basin is estimated to be about 70,000 acre-feet.

Yield of Wells. Wells in the alluvial basin generally yield from 100 to 600 gallons per minute with a range in specific capacity of from three to twenty. Wells tapping the older surrounding formations usually yield from two to five gallons per minute but occasionally yield as much as 50 gallons per minute. The specific capacity of wells in the older formations is usually very small.

#### Upper Ventura River Basin

Upper Ventura River Basin lies within the Upper Ventura River subunit which includes the Ventura River Valley, the Coyote Creek drainage area, and that portion of the San Antonio Creek drainage area that lies downstream from Ojai Valley. The basin ranges in elevation from 200 to more than 800 feet above sea level, and consists of about 4,990 acres underlain by alluvium. Water-bearing alluvial deposits of very limited areal extent also occur along Coyote Creek and San Antonio Creek, but these deposits are not considered to be of sufficient size to be regarded as ground water basins.

Geology. The alluvium consists of Upper Pleistocene and Recent deposits of gravel, sand, and clay. Well logs indicate the alluvium of Ventura River valley to vary from 60 to 10 feet in depth. In the San Antonio and Coyote Creek areas, it apparently varies from 5 to 30 feet in depth. These deposits are flanked by Tertiary sediment consisting of marine and continental sandstone, conglomerate, and shale, and include the Rincon, Modelo, Vaqueros, Sespe, Coldwater, and Cozy Dell formations. The Sespe formation underlies a large portion of the Coyote Creek drainage area and is composed chiefly of well cemented sandstone with intercalated lenses of conglomerate. The sandstone is locally fractured. The conglomerates occur as both poorly and well cemented deposits. It is often difficult to distinguish the conglomerates from overlying alluvium in well logs. Some water wells penetrating the Modelo formation obtain water of inferior quality.

The Ventura River is an antecedent stream that has cut across the regional structure and does not flow along a structural trough. The Tertiary rocks are generally folded and faulted, but the Recent deposits are relatively undisturbed.

Occurrence of Ground Water. Ground water occurs in alluvium and to some extent in the fractures and interstices of the Tertiary formations. In general, free ground water conditions prevail throughout the entire subunit. However, locally confined bodies of ground water may exist. While wells in the Sespe formation are being drilled, the water level occasionally rises, indicating the existence of localized confined bodies of ground water.

Movement of Ground Water. Ground water moves through the alluvium following the slopes of the surface drainage, ultimately discharging into the Lower Ventura River Basin below Foster Park. Directions of flow are more closely indicated by ground water contours on Plates 14-A, 15, and 16. The flow is generally indicated as crossing this basin in an east-west direction. This is not a true flow direction.



suggesting that they cut the alluvium or form barriers to movement of ground water.

Replenishment and Depletion of Ground Water. Ground water is replenished chiefly by percolation from the Ventura River and to a lesser extent by percolation of direct rainfall and the unconsumed portion of water applied for irrigation and other uses. A slight amount of recharge is probably derived from subsurface inflow through the flanking Tertiary formations. Ground water is depleted by pumped extractions, consumptive use of phreatophytes, effluent discharge, and subsurface outflow.

Subsurface Inflow and Outflow. Subsurface inflow is practically negligible being limited to seepage through fissures and pores in the Tertiary formations. In 1906, the City of Ventura constructed a partial subsurface barrier in the alluvium of the Ventura River near Foster Park. The purpose of the barrier was to create rising water to be diverted for domestic and irrigation purposes. The easternmost end of this barrier was not completed, and a perennial subsurface flow exists around this end. This flow was estimated by the slope area method described in Chapter B-VI and was found to vary between 75,000 and 100,000 gallons per day or about 100 acre-feet per year.

Ground Water Storage Capacity and Specific Yield. Total storage capacity of the basin is estimated to be about 10,000 acre-feet. The average specific yield of the contained sediments is estimated to be about eight per cent.

Yield of Wells. Irrigation wells in the alluvium yield about 600 gallons per minute with specific capacities ranging from 10 to 200. Both well yield and specific capacity are influenced by the regimen of the Ventura River. Following cessation of surface flow in the river, both yields and specific capacities fall below the above values.



## Lower Ventura River Basin

Lower Ventura River Basin includes the alluvial deposits of the Ventura River that lie between Foster Park and the ocean, and the basin ranges in elevation from sea level to about 200 feet above sea level. It has a surface area of about 2,670 acres. The valley floor of Canada Larga has been excluded from this basin, since the alluvial deposits in this valley are shallow and contain little water. In the southern end of the basin, alluvium overlies and is probably hydraulically isolated from the San Pedro formation. The San Pedro formation in this area appears to be hydraulically connected with the Mound Basin and is considered herein a part of that basin.

Geology. The alluvial fill of the basin consists of gravel, sand, and clay. It is surrounded and underlain by older, generally less permeable sedimentary formations. These include the San Pedro, Santa Barbara, Pico, Modelo, Rincon, Queros, and Sespe formations. At its north end, the basin is connected to Upper Ventura River Basin near Foster Park, and at the south end it is bounded by the ocean.

Within this basin, Ventura River is an antecedent stream. It crosses the axis of the Ventura Avenue anticline near the center of the basin. Downstream from this axis, formations older than the alluvium dip southward and strike in an easterly direction. With the exception of the Pleistocene San Pedro formation, the flanking formations are generally nonwater-bearing. The San Pedro formation consists chiefly of gravel, sand, silt, and clay.

Sea-Water Intrusion. No evidence available conclusively indicates that sea water has invaded the basin. The electric log of one well near the river mouth shows that at the time of drilling, the alluvial deposits contained highly mineralized water. It is uncertain as to whether this condition was due to intrusion of sea water or to pollution from local sources. Two wells near the

river mouth tap only the underlying San Pedro formation and provide no indication of the quality of water occurring in the alluvium.

Occurrence of Ground Water. The principal water-bearing formation is the late Quaternary alluvium of the Ventura River which varies from 60 to 100 feet in thickness. Terrace and alluvial deposits flanking the main body of alluvium, Plate B-1A, are shallow and would produce only minor quantities of water.

The San Pedro formation flanks and underlies the alluvium near the mouth of Ventura River. It dips about 35 degrees toward the south and strikes to the east extending into Mound Basin. Available data suggest that the San Pedro formation near the river mouth is at least partially hydraulically isolated from the river alluvium by relatively impervious material, possibly of lagunal or Paludal origin. The alluvium is considered to be within the Lower Ventura River Basin overlapping the San Pedro formation which belongs hydrologically within Mound Basin. This conclusion is substantiated by the following observations:

1. Static water levels in wells tapping the San Pedro formation have been above the elevation of the bed of the Ventura River indicating that ground water in the San Pedro formation is confined.

2. The electric log of one of the above wells indicated water of poor quality in the river alluvium; yet this same well has continually produced fresh water from the underlying San Pedro formation.

3. Water levels in wells tapping the San Pedro formation fluctuate in rapid response to tidal fluctuations, further indicating that ground water in the San Pedro formation is confined.

Movement of Ground Water. There are few wells situated in Lower Ventura River Basin; consequently, no ground water contour map was constructed of this area. In general, ground water moves in a downstream direction, ultimately discharging into the ocean. No barriers to ground water movement are known to exist.

Replenishment and Depletion of Ground Water. The basin is replenished by percolation from the Ventura River, by percolation of rainfall and the unconsumed portion of water applied for irrigation and other uses, as well as by subsurface inflow from Upper Ventura River Basin. Inflow from flanking Tertiary sediments is probably small. Depletion occurs by surface and subsurface outflow, limited pumped extractions, and consumptive use of phreatophytes.

Subsurface Inflow and Outflow. Subsurface flow in the alluvium of the Ventura River near Foster Park constitutes one of the principal sources of supply for Lower Ventura River Basin. Subsurface outflow from the basin probably discharges to the ocean during periods of high ground water level.

Ground Water Storage Capacity and Specific Yield. Pumping draft on Lower Ventura River Basin is negligible. There are no irrigation wells, a few abandoned domestic wells, and one sump pump. For this reason, no estimates of change in storage were compiled for this basin.

Yield of Wells. There are no known irrigation or domestic wells operating in Lower Ventura River Basin which obtain water from the alluvial fill.



## Ground Water Basins Within Santa Clara River Hydrologic Unit

Ground water basins within the Santa Clara River Hydrologic Unit include Piru, Fillmore, Santa Paula, Mound, Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins. These basins are the most productive in Ventura County. Plate 1 shows the location of the ground water basins, and their physical characteristics are summarized in Table 11. Plate B-1B shows details of geologic structure and extent of formations in this hydrologic unit.

### Eastern Basin

Eastern Basin lies within Los Angeles County; more explicitly it comprises the water-bearing formations of that part of the Santa Clara River Valley lying east of Ventura County. Since it is not in Ventura County, it was not studied in detail during the course of this investigation. It is discussed here because it is tributary to other basins in Ventura County. Pumping from this basin effects the regimen of both surface and subsurface flow in the Santa Clara River. The boundaries of Eastern Basin were not determined exactly, except for the boundary with Piru Basin on the west.

Geology. The watershed tributary to Eastern Basin contains sedimentary formations of marine and non-marine origin, some volcanic rocks, and large areas of granitic and metamorphic rocks. These formations are shown on Plate 10 and include alluvium, Saugus and Pico formations, Ridge Basin group, "Santa Margarita" Modelo, Vaqueros, Mint Canyon and Martinez formations. Of these formations, the Saugus and Quaternary alluvium are of principal interest. Water derived from

areas of non-marine formations may be fairly high in boron due to occurrence of boron minerals in these sediments.

The Saugus formation in this area consists of continental sand, clay, and poorly cemented gravel and attains a maximum thickness of 2,500 feet. These materials have been faulted, folded, and eroded. In the valley areas the Saugus formation is overlain by up to 100 feet of alluvial sand and gravel with some clay and silt.

Occurrence of Ground Water. Ground water is derived principally from wells tapping the Saugus formation and the Quaternary alluvium. It is known that ground water within the deeper aquifers often occurs as confined water whereas that within the alluvium is usually unconfined. No attempt was made in this investigation to delimit the extent of the different aquifers in Eastern Basin.

Movement of Ground Water. No ground water contour maps were constructed in Eastern Basin by this Division during this investigation. Ground water contour maps of this area are published in "The Annual Report on Hydrologic Data" by the Los Angeles County Flood Control District.

Replenishment and Depletion of Ground Water. Ground water is replenished by stream percolation, penetration of direct precipitation and the unaccounted portions of water applied for irrigation and other uses as well as imported water released by the City of Los Angeles from Bouquet Canyon Reservoir, and also to a minor extent by subsurface inflow from the older semi-permeable formations that flank the basin. The ground water basin is depleted by pumped extractions, consumptive use of phreatophytes, and effluent discharge.

Subsurface Inflow and Outflow. An undetermined amount of inflow enters the basin from older semi-permeable formations that flank the water-bearing sediments. Subsurface outflow from Eastern Basin is negligible and is discussed in the paragraph on subsurface inflow to Piru Basin.

Ground Water Storage Capacity and Specific Yield. No attempt was made to estimate change of storage or total storage capacity within Eastern Basin during this investigation.

Yield of Wells. No measurements of well discharge were made in this basin, although both irrigation and domestic wells exist. Several highly productive wells tap the alluvial sands near the river and are supplied directly by percolation from that source. One such well reportedly yields 2,000 gallons per minute. Irrigation wells are also known to tap the Saugus formation, but the yields of such wells are not known.

### Piru Basin

Piru Basin ranges in elevation from 470 feet to 800 feet. The highest elevation within the watershed is 4,592 feet attained at Hopper Mountain. It comprises a surface area of about 6,520 acres. The greater portion of the ground water basin underlies the alluvial area of the Santa Clara River Valley. The eastern boundary of the basin is at Blue Cut which is located about one mile west of the Los Angeles County line. The western boundary is arbitrarily located as shown on Plate B-1B.

Geology. The principal water-bearing formations of Piru Basin are alluvium of Recent and upper Pleistocene age and the San Pedro formation. Rocks adjacent to the valley floor include the Sespe, Vaqueros, Modelo, "Santa Margarita", and Pico formations, all of which are essentially nonwater-bearing in this area but which may contribute water of poor quality to the water-bearing material.

Alluvium in Piru Basin is about 85 to 200 feet thick and consists of river deposited sand and gravel of Recent and upper Pleistocene age which is not readily differentiated from the San Pedro formation. In Blue Cut at the extreme east end of the basin, alluvium is about 6 to 15 feet thick. On the south side of



Piru Basin alluvium overlies a shelf-like feature of nonwater-bearing rocks (see Geologic Section J-J', Plate 12-A).

The San Pedro formation does not outcrop in this basin, but it is topped at depth by many wells.

Water wells reach depths of up to 1,000 feet in Piru Basin and their logs indicate that the San Pedro formation is characterized by gravel, sand, and some clay. Several water wells which were in the process of being drilled were visited in the course of the investigation. Samples of material taken from these wells indicate that most of the San Pedro formation, to depths of 800 feet, was deposited under conditions similar to those which prevail in the Santa Clara River today. The nature of the sediments deeper than 800 feet is not well known. Samples from an oil well drilled near Cavin Road on the north side of the river east west of the center of the basin are comprised of similar materials to depths of 1,000 feet. The silt content increases appreciably to 1,200 feet, the maximum depth of the well. The electric log of an oil well about one mile east of the town of Fillmore indicates that thick interbedded sands and clays extend to depths of 4,000 feet.

The San Pedro formation has been folded along the Santa Clara River syncline. At the Oak Ridge and San Cayetano faults older rocks have been thrust over the formation. Two oil wells in the mountains about one mile north of the valley first penetrate the Modelo sandstone and shale, then the San Cayetano fault, and finally the San Pedro formation which is only gently folded. The west angle of dip of the San Cayetano fault as shown by these wells is about 30 degrees toward the north. The Oak Ridge fault dips about 60 degrees southward as evidenced in oil wells drilled on Oak Ridge south of the Santa Clara River valley.

The trough axis of the Santa Clara River syncline is folded upward southward east of the town of Piru, where the San Pedro formation has apparently been

truncated by erosion. The San Pedro formation is reduced in cross-sectional area westward from Piru to the State Fish Hatchery, where the narrowest part of the valley is located. Well log data indicate that the cross-sectional area may also be slightly reduced by a gentle upwarp of the base of the San Pedro formation near the fish hatchery.

Occurrence of Ground Water. Ground water is generally unconfined in both the San Pedro formation and the overlying alluvium.

Movement of Ground Water. Ground water generally moves westward, as shown on the water level contour maps, with minor contribution from the north and south sides of the basin (see Plates 14-B, 15-B and 16-B). The water table slope appears to be fairly steep just southeast of Piru, and it is possible that this steep slope may be related to the upturned edge of the San Pedro formation beneath the alluvium.

Slope of the water table decreases from an area south of Piru and continues to decrease toward the State Fish Hatchery which is located on the Piru-Fillmore Basin boundary. Cross-sectional area of the water-bearing materials is at the least near the Fish Hatchery where it results in a steeper water table slope. Farther west the slope decreases as the cross-sectional area increases. The point where the steepening occurs cannot be accurately determined, but its location appears to vary with water levels in Piru Basin. The boundary of Piru Basin was drawn arbitrarily near the Fish Hatchery where the maximum amount of rising water usually occurs, but could also be located to the east or to the west of the assumed boundary. It is clear that as long as a westward gradient of the water table exists, subsurface outflow will continue. Historically, this westward gradient has always existed; although it has become less as the basin was depleted and greater as the basin was replenished. Because of the considerable depth of the San Pedro formation at the State Fish Hatchery it is likely that subsurface

flow out of Piru Basin will continue as long as water levels are higher than in Fillmore Basin. There is no evidence available indicating the presence of a fault which would function as a ground water barrier, as suggested by previous investigators.

Replenishment and Depletion of Ground Water. Ground water in Piru Basin is replenished by percolation in stream channels and in the Piru spreading grounds, by percolation of direct precipitation and the unconsumed portion of water applied for irrigation and other uses, and probably by a minor amount of subsurface inflow from adjacent semi-permeable formations. Ground water is depleted by pumped extractions, consumptive use of phreatophytes, effluent discharge, and by subsurface flow into Fillmore Basin.

Subsurface Inflow and Outflow. Subsurface flow into the Piru Basin from the Eastern Basin is probably negligible because of the thin alluvial cover at the basin boundary in Blue Cut. Subsurface flow out of Piru Basin into Fillmore Basin has been estimated by the rising water method (see p. B-42) to be thirty second-feet. Subsurface flow out of Piru Basin will occur whether there is rising water or not, but will be decreased somewhat after rising water stops and as the water table is lowered and its gradient decreased.

Ground Water Storage Capacity and Specific Yield. Results of change of ground water storage estimates are discussed in Chapter II. Forty-five well logs were used to determine specific yield of the sediments. The mean weighted specific yield of the interval between the highest water levels of 1944 and the lowest of 1951 is estimated to be 16 per cent. To estimate total storage capacity of the ground water basin, it was assumed that usable depth of the ground water basin is 1,000 feet, that the average area at depth is about 6,000 acres, and that the specific yield does not change appreciably with depth. By multiplying these figures,



the storage capacity for Piru Basin is estimated to be 6000 x 1000 x .16 or 960,000 acre-feet, or on the order of one million acre-feet.

Yield of Wells. Yield of irrigation wells in Piru Basin varies from 600 to about 2,000 gallons per minute, with an estimated average of 800 gallons per minute. Specific capacity averages about 70. Yield of wells on the shelf on the south side of Piru Basin is fairly high when water levels are high, but when the water level falls and the alluvium is dewatered the wells go dry.

### Fillmore Basin

Fillmore Basin which comprises a surface area of about 16,870 acres ranges in elevation from 280 to 470 feet in the Santa Clara River channel. Maximum elevation in the immediate drainage area is 4,959 feet at Santa Paula Peak. Two prominent features of this area include Timber Canyon which reaches an elevation of about 2,200 feet, and the Sespe uplands north of the Santa Clara River and west of Sespe Creek.

Geology. Water-bearing materials underlying the basin include alluvium of Recent and Pleistocene age and the San Pedro formation. Formations adjacent to Fillmore Basin include the Santa Barbara, Pico, Modelo, Vaqueros, and Sespe which are essentially nonwater-bearing, but may contribute limited amounts of water of poor quality to the water-bearing materials. See Geologic Section H-H, Plate 12-A, for general relationships of the water-bearing materials.

The alluvium comprises gravel, sand, and some clay up to 250 feet in thickness. The alluvium is difficult to differentiate from the underlying San Pedro formation in the valley floor area of the basin. A study of water well logs in the Sespe uplands indicates that the alluvium is underlain, at least in part, by the San Pedro formation. The alluvium in the Sespe uplands consists of upper Pleistocene and Recent alluvial fans which have been deposited on the

turned and eroded edges of the San Pedro and older formations (See Geologic Section H-H', Plate 12-A). The upper Pleistocene (or older) alluvium has been partly dissected and somewhat folded. It is being dissected in some areas and covered by Recent alluvium in others. The alluvium in the Sespe uplands comprises gravel, gravelly clay, and clay and is generally reddish in color.

Timber Canyon, located about four miles northeast of Santa Paula, is floored by Recent alluvium. A large alluvial cone extends from Santa Clara River valley up the floor of Timber Canyon. The surface material on this cone is extremely coarse, poorly sorted, subangular gravel. Water well logs indicate that this coarse material contains considerable clay and that the cone is up to 100 feet thick just north of Highway 126.

On the south side of Fillmore Basin, in the Bardsdale area, the alluvium overlies a shelf of semi-permeable rocks which have been thrust up by the Oak Ridge fault. The alluvium overlying this shelf is up to 180 feet thick. It is probable that this alluvium includes upper Pleistocene materials.

The San Pedro formation outcrops north of the valley floor from the town of Santa Paula to the Sespe uplands, where it is concealed beneath alluvium. The San Pedro formation dips about 40 degrees to the south near Santa Paula and becomes steeper eastward until it is overturned at Timber Canyon. Cores from an oil well northwest of the town of Fillmore indicate that the San Pedro formation is relatively flat lying at depth below the gently dipping San Cayetano fault and the valley area of Sespe Creek. The structure of the San Pedro formation in the Sespe uplands is concealed by alluvium, but available data suggest that additional unknown faults complicate the geology of this area.

The San Pedro formation is about 4,000 feet thick in this basin and it consists of gravel, sand, and clay. The uppermost portion of the formation is stream deposited, probably by the ancient equivalent of the Santa Clara River. The lower and some of the middle portion of the San Pedro formation contains

marine fossils which indicate deposition in a shallow marine environment. Field inspection of the San Pedro formation on the north side of the Fillmore Basin indicates that the beds are extremely lenticular and discontinuous. Clays are fairly common, but are also discontinuous.

Structurally Fillmore Basin is a part of the Santa Clara River syncline. Along the Oak Ridge fault on the south of the basin, the semi-permeable formations underlying Oak Ridge have been thrust up against the San Pedro formation. The San Cayetano fault swings northward near the town of Fillmore and does not directly affect the ground water geology west of Sespe Creek.

The cross-sectional area of the San Pedro formation is slightly reduced by local warping of the Santa Clara River syncline east of Santa Paula, where the assumed boundary of the basin is located. Water levels and available geologic data do not indicate faulting in this area.

A complex feature exists in Fillmore Basin on the south edge of the Sespe uplands just north of Highway 126. Inspection of the older alluvial sediments in the small hills in this area indicates that an anticlinal structure is present as shown on the geologic map (Plate B-1B). Cores from an oil well drilled here indicate the presence of faulted and folded sediments at shallow depths. It is possible that an east-west trending fault which may affect ground water exists in this area, but water level contours do not indicate the presence of such a fault.

Occurrence of Ground Water. Ground water occurs in the San Pedro formation and in the overlying alluvium and is essentially unconfined.

Movement of Ground Water. Ground water moves westerly in Fillmore Basin with some minor contribution from the south and north sides. There is a decrease in cross-sectional area of water-bearing materials from the vicinity of Sespe Creek to the arbitrary boundary between Fillmore and Santa Paula Basins. Slope



the water table decreases westward toward this boundary. Near the narrowest point which is taken as the western boundary of Fillmore Basin, the slope of the water table increases, decreasing again as the cross-sectional area increases into Santa Paula Basin. The point of steepest slope appears to be variable under different water level conditions, and is actually a fairly wide zone rather than a sharp line. This is the reason that an arbitrary boundary is used, just as between Piru and Fillmore Basins. As far as can be determined, no cross fault which affects ground water exists at this boundary.

Replenishment and Depletion of Ground Water. Ground water in Fillmore Basin is replenished by subsurface inflow, by stream percolation, by percolation of direct precipitation and the unconsumed portion of water applied for irrigation and other uses, and probably by a minor amount of subsurface flow from the San Pedro formation and adjacent semi-permeable formations. Ground water is depleted by pumped extractions, consumptive use of phreatophytes, effluent discharge, and subsurface outflow.

Subsurface Inflow and Outflow. Subsurface inflow into Fillmore Basin from Piru Basin has been estimated by the rising water method to be about thirty second-feet. Well log data are not sufficient to accurately check this estimate by the slope-area method. Subsurface outflow from Fillmore Basin into Santa Paula Basin has been estimated by the rising water method to be about sixteen second-feet. Subsurface outflow from Fillmore Basin will continue, even after rising water stops, but it is likely that the underflow would decrease somewhat.

Ground Water Storage Capacity and Specific Yield. Results of ground water storage estimates are discussed in Chapter II. One hundred five well logs are used to estimate specific yield and change of storage. The change of storage estimate includes the Sespe upland area. The mean weighted specific yield of

the interval between the highest and lowest historic water table is estimated to be 12 per cent. The total storage capacity of the upper thousand feet of Fillmore Basin is probably on the same order of magnitude as Piru Basin, or about one million acre-feet using an estimated area of 12,000 acres. The average specific yield is smaller in Fillmore Basin, but the area is larger than Piru Basin. The maximum total storage capacity of the basin is unknown because the effective depth of the basin has not been determined. This depth may reach 4,000 feet, which is the base of the San Pedro formation as found in oil wells near the town of Fillmore.

Yield of Wells. Irrigation wells in Fillmore Basin yield up to 2,100 gallons per minute, and their average yield is about 700 gallons per minute. Specific capacity of the wells varies considerably but probably averages 50. Yields of wells on the shelf on the south side of the basin and on part of the Sespe uplands are generally smaller than in the valley floor, due to limited depth of alluvium.

#### Santa Paula Basin

Santa Paula Basin ranges in elevation from 140 to 280 feet, although the maximum elevation in the local drainage area is 2,750 feet on Sulphur Mountain. The ground water basin underlies the flat alluvial area of the Santa Clara River Valley and comprises a surface area of about 13,520 acres. The boundary between Santa Paula and Fillmore Basins has been discussed under the description of the latter basin. Between Santa Paula Basin and Mound Basin, the boundary is also an arbitrary line as discussed below.

Geology. Water-bearing materials in Santa Paula Basin include the alluvium of Recent and upper Pleistocene age and the San Pedro formation. Rocks underlying the San Pedro formation and adjacent to the basin include the Santa

Barbara, Pico, Modelo, Vaqueros, and Sespe formations, which are generally semi-permeable and may contain water of poor quality.

The alluvium consists of up to 200 feet of stream deposited gravel, sand, and some clay and cannot be easily differentiated from the underlying San Pedro formation. The alluvium near Saticoy and in the northwestern portion of the basin consists of yellow silty clay overlying and interbedded with stream gravels as shown on Geologic Section G-G' of Plate 12-A. Lenticular gravels interbedded with this clay may locally yield water of poor quality to wells. The clay forms a cap over the gravels and pinches out to the south and to the east. This yellow silty clay was probably deposited as alluvial fans by streams draining the area north of the basin. Similar silts are still being deposited in the area.

The San Pedro formation consists of 4,000 feet of gravel, sand, and clay. The lower third of this formation contains fossils indicating a marine origin. The upper two-thirds is generally devoid of fossils and consists primarily of stream deposits. Exposures of the San Pedro formation exhibit irregular bedding. Scour and fill features are common with individual gravels often grading laterally into sands or silts within a very short distance. It is probable that extreme variations also exist in the San Pedro formation underlying the valley floor, but local changes cannot be detected from drillers' logs.

The deepest water well logs indicate that gravels of the San Pedro formation persist to depths of at least 800 feet. Oil well logs and outcrops indicate that the total thickness of the San Pedro formation may be 4,000 feet. The total effective thickness is unknown, as far as water-bearing characteristics are concerned, but it is probably at least 1,000 feet as indicated by one oil well log.

The most significant structural features in Santa Paula Basin are the Santa Clara River syncline, the Oak Ridge fault, and the Saticoy fault. As discussed in Chapter B-IV of this appendix, it is probable that the Saticoy fault is a branch of the Oak Ridge fault, although it may simply be an extension. Where



it can be traced, the Saticoy fault forms the boundary between Santa Paula and Oxnard Forebay Basins, but since it cannot be traced in the bed of the Santa Clara River, an arbitrary boundary was used at that location. The San Pedro formation has been cut off on the south by the Oak Ridge fault. The upturned edge of the San Pedro formation is exposed on the north side of the basin. It has been folded into the Ventura Avenue anticline and the Canada Larga syncline as shown on Plate B-1B. These structures probably affect ground water in the outcrop area of the San Pedro, but they appear to die out to the east and probably do not affect ground water in Santa Paula Basin.

Occurrence of Ground Water. Ground water occurs in the San Pedro formation and in the overlying alluvium. The ground water body in most of the basin is unconfined, but where clay lenses exist, confined ground water is evident from water level records of wells.

Movement of Ground Water. Ground water generally moves in a westerly direction as shown by ground water elevation contour maps (Plates 14-B, 15-B, and 16-B). At the west end of the basin the Saticoy fault forms a barrier impeding movement of ground water into Oxnard Forebay Basin. The effectiveness of this fault as a ground water barrier is demonstrated by a pronounced difference in water level elevation on either side of the fault. On the upstream side of this fault, near Saticoy, water levels range from 50 to 100 feet higher than the levels existing on the downstream side.

Between Santa Paula Basin and Mound Basin a relatively steep gradient in water levels exists. The cause of this steeper gradient is not readily apparent. There is no distinct and sudden drop in water level as characterized by a fault barrier, and it is believed that the steep gradient is due to a decrease in the permeability of the sediments underlying the area, although there may be some faulting in the San Pedro formation.

Replenishment and Depletion of Ground Water. Ground water is replenished by stream percolation, by penetration of direct precipitation and the un-  
consumed portion of water applied for irrigation and other uses, by subsurface  
flow from Fillmore Basin, and probably by a minor amount of subsurface inflow  
from older formations on the south side of the basin.

Field inspection of outcrops of the San Pedro formation reveals great  
regularity in bedding, and also considerable amounts of silt and clay. It can  
be assumed that the upturned edge of the San Pedro is in hydrologic continuity  
with the aquifers in the same formation from which pumping occurs underlying the  
valley floor. Water level data and geologic control are not available for a  
reliable estimate of subsurface inflow to the basin from the outcrop.

The ground water basin is depleted by pumped extractions, consumptive  
use of phreatophytes, effluent discharge, and subsurface flow into Oxnard Forebay  
and Mound Basins.

Subsurface Inflow and Outflow. Ground water movement into and out of  
Santa Paula Basin was estimated by the rising water method. Sixteen second-feet  
was estimated as subsurface inflow from Fillmore Basin. Ten second-feet was  
estimated as outflow into the Oxnard Forebay Basin. Additional subsurface out-  
flow also occurs into Mound Basin through the San Pedro formation and could  
amount to more than ten second-feet. Geologic data necessary for an accurate  
estimate of subsurface outflow into Mound Basin are lacking.

Ground Water Storage Capacity and Specific Yield. Estimates of change  
in storage are discussed in Chapter II. Some 67 well logs were used to obtain  
these estimates. Weighted average specific yield of the sediments in the interval  
between the water table elevations of 1944 and 1951 is estimated to be ten per  
cent. Change of storage in the outcrop area of the San Pedro formation could not  
be determined because water level and well log data were unavailable. Such  
changes could conceivably be large.



Using an estimated area of 10,000 acres and a depth of about 800 feet, total storage capacity of the ground water basin was estimated to be about 800,000 acre-feet. Additional storage capacity probably exists below this depth and in the outcrop area, but data to estimate its amount are lacking.

Yield of Wells. Irrigation wells in Santa Paula Basin yield from 300 to 1,500 gallons per minute and average about 700 gallons per minute.

### Mound Basin

Mound Basin ranges in elevation from sea level to over 400 feet and has a surface area of about 12,300 acres. It is bounded by hills to the north, Santa Paula Basin to the east, and Oxnard Plain and Oxnard Forebay Basins to the south.

Geology. The principal water-bearing formation in Mound Basin is the San Pedro. Other formations include the overlying alluvial deposits and the underlying Santa Barbara formation. The Recent and upper Pleistocene alluvium is characterized by yellow silty clay containing occasional lenses of sand and gravel. It varies from 100 feet to 500 feet in thickness. The yellow silty clay has been deposited as alluvial fans by streams draining the area to the north. It appears that these yellow clays grade into and interfinger with deposits of Oxnard Plain Basin along the present course of the Santa Clara River. Gravel, sand, silt and clay of upper Pleistocene age outcrop along the north edge of the basin and dip southward as much as 12 degrees. These particular outcrops are at the base of the upper Pleistocene deposits and contain marine fossils which indicate littoral deposition.

The San Pedro formation lies unconformably beneath the alluvium and outcrops in the hills north of Mound Basin where it is 4,000 feet thick. It consists of gravel, sand, silt, and clay. Marine fossils are found throughout the



section of outcrop, but previous investigators believe that most of the upper part of the San Pedro formation is continental in origin and that the marine fossils are reworked. The upper 500 to 1,000 feet of the San Pedro formation contains many permeable sand and gravel members. Below these members are a series of beds which are predominantly silts and clays and are in turn underlain by gravels. The permeable members of the outcrop may be continuous with those beneath the Mound Basin. Exposures show these sands and gravels to be extremely particular. Scour and fill features are common, and individual beds cannot be traced more than several hundred feet.

From the outcrop, the San Pedro formation extends westward under the alluvium of the Ventura River Valley and into the ocean. Contours of the ocean floor indicate small irregularities which parallel the trend of the San Pedro formation and suggest that it outcrops there. The San Pedro formation west of the Ventura River is mostly coarse gravel, with minor sands and clays. On the east side of the Ventura River, however, the formation is mostly fine sand, silt and clay with only minor gravels. This rapid lateral change in lithology cannot usually be traced down the dip of the beds, but where suitable exposures are found it appears that the down dip variations are as great as the lateral variations.

The structure of Mound Basin is essentially that of a syncline as shown by cross-section B'-B", Plate B-1B. The San Pedro formation is folded in the Santa Clara River syncline and in the Montalvo anticline, and is displaced by the Saticoy fault (see Plate B-1B). The north limb of the Santa Clara River syncline is exposed in the hills north of the basin. Well log data indicate that the Saticoy fault extends a short distance westward from Saticoy, but either dies out or cannot be detected westward from a point north of Montalvo. Water well logs south of Ventura do not indicate that the Saticoy fault extends to the beach. Surface exposures and well logs indicate that complex folding and faulting has

affected the area north of the Santa Clara River and south of the Saticoy fault. Cores from oil wells in and near the Santa Clara River west of Montalvo indicate that the south flank of the Santa Clara syncline dips steeply to the north. The Montalvo anticline in the area west of Montalvo appears to be asymmetrical and probably overturned to the north. North and east of Montalvo the Montalvo anticline appears to be nearly symmetrical but is probably displaced by the Saticoy fault.

An excavation on the small hill due north of Montalvo reportedly exposed sediments which dip sixty-five degrees southward. This outcrop is now covered, but the sediments in the area appear to be similar to the non-marine San Pedro formation. Cores from an oil well northwest of Montalvo indicate faults and steeply dipping sediments below 200 feet. These examples of faults and steeply dipping sediments are in themselves of little significance, since they cannot be correlated. They are important because they indicate that the water-bearing sediments in this part of Mound Basin have been involved in complex folding and faulting.

#### Seaward Extension and Hydraulic Continuity of Aquifers With the Ocean.

A question of some importance in Mound Basin is the possibility of hydrologic continuity of the aquifers of the San Pedro formation with the ocean. The only place where this continuity may exist is west of the Ventura River where the south dipping beds strike westward into and beneath the ocean. Slope of the offshore topography is very gentle and it is unlikely that the San Pedro formation near the axis of the Santa Clara River syncline would outcrop on the ocean floor unless the syncline were folded upward. Offshore seismic data suggests that the syncline continues seaward without such upwarping. The gently sloping sea floor is underlain by silty clay in areas where samples have been taken.

When water levels are high in Mound Basin, a seaward gradient exists, suggesting subsurface outflow. Water levels fall below sea level during dry periods, suggesting that sea water intrusion occurs. Detailed measurements of each wells and wells in and west of the Ventura River Valley perforated in the San Pedro formation show tidal fluctuations which lag behind the ocean tides by only a few minutes. This short time lag indicates that the aquifer is affected by tidal loading but does not necessarily indicate hydraulic continuity with the ocean. A shallow abandoned well near one of the City of Ventura's deep wells on the beach showed more than an hour's time lag, indicating possible hydraulic continuity of the minor shallow aquifers with the ocean.

Available evidence indicates, therefore, that outflow of fresh water or flow of sea water is possible, but data are not available to estimate the quantity. Up to the time of writing this report no evidence of sea water intrusion has been found in quality of water from wells in the San Pedro formation which is closest to the ocean.

Occurrence of Ground Water. Wells obtain water from sands and gravels in the San Pedro formation and possibly from alluvium of upper Pleistocene age. It has been necessary to drill water wells in Mound Basin to depths of 400 to 500 feet in order to obtain water from these gravels. The gravels of the San Pedro formation are overlain by up to 500 feet of confining silty clay. Wells near the beach south of Ventura flow when water levels are high.

Movement of Ground Water. Ground water in Mound Basin generally moves seaward toward the ocean as shown by the water level contours on Plates 14-B, 15-B, and 16-B. Movement may occur from Oxnard Forebay Basin as well as Santa Barbara Basin. Some movement may possibly occur from Oxnard Plain Basin and from the outcrop area of the San Pedro formation north of the Mound Basin. A water level recorder installed on a well about 60 feet south of Highway 101 and just



west of the Ventura River showed no fluctuations as a result of pumping a well about 500 feet to the south, which has a drawdown of about 60 feet. Both wells are perforated, however, in the San Pedro formation which dips about 35 degrees southward in this vicinity. The lack of reaction in the recorder well indicates that there is limited movement of ground water across the bedding of the San Pedro formation.

Replenishment and Depletion of Ground Water. Replenishment of Mound Basin occurs by subsurface inflow from adjacent basins and from the outcrop area of the San Pedro formation, which is in turn replenished by rainfall penetration and stream percolation. The basin is depleted by pumped extractions and possibly subsurface outflow.

Subsurface Inflow and Outflow. Subsurface inflow occurs from Santa Paula Basin, from the outcrop area of the San Pedro formation and possibly from Oxnard Forebay and Oxnard Plain Basins when water levels are favorable. As discussed in the paragraphs on Lower Ventura River Basin, inflow from the alluvium of that basin is probably negligible. Some subsurface inflow from the seaward extension of the aquifers probably occurs during periods of low water level.

Subsurface outflow from Mound Basin into Oxnard Plain Basin may occur through the San Pedro formation beneath Oxnard Plain Basin when water levels are suitable, but the degree of hydrologic continuity of the San Pedro formation between these two areas is uncertain and may be negligible. Some subsurface outflow toward the ocean may occur during periods of high water level.

Ground Water Storage Capacity and Specific Yield. It is estimated that very little, or no change of storage occurs within Mound Basin. Since water level and well log data are lacking in the outcrop area, change in storage in the San Pedro formation north of the basin could not be estimated, although such changes may be fairly large.

Yield of Wells. Wells in Mound Basin yield from 300 to 1,500 gallons minute from the San Pedro formation. The estimated average yield is 700 lons per minute and the average specific capacity about 70.

### Oxnard Forebay Basin

Ground surface elevations within Oxnard Forebay Basin vary from about to 150 feet above sea level and the basin occupies an area of about 6,170 acres. water-bearing sediments of Oxnard Forebay Basin are similar in several respects those of Oxnard Plain Basin except that the Oxnard Forebay is a free ground er area. This basic difference is so important that the areas have been ferentiated and will be described separately.

Geology. Formations in Oxnard Forebay Basin include Recent and upper istocene alluvium underlain unconformably by the San Pedro formation and, in mall area, by the Santa Barbara formation.

Alluvium of Recent and upper Pleistocene age is the most important mater- in the Oxnard Forebay since it forms the ground water reservoir for most of water used in Oxnard Plain Basin. The alluvium consists of up to about 400 t of river deposited gravels, clays and sand being common below 200 feet. alluvium has been deposited unconformably upon the upturned San Pedro and ta Barbara formations. Geologic Section K-K', Plate 12-B, shows that the base the upper Pleistocene has also been folded, while the upper gravels have not n appreciably disturbed, resulting in a local unconformity within the materials e designated alluvium. This interpretation of the data would suggest that some the lower part of "upper Pleistocene" alluvium may be middle Pleistocene in age, ce parts of it would have been deposited while the unconformity was being formed the middle Pleistocene orogeny; or the lower part of the alluvium is in reality er Pleistocene in age, and folding has occurred in upper Pleistocene time. The



latter possibility is preferred, since upper Pleistocene vertebrate fossils have been found near Ventura in the terrace deposits which dip 10 to 15 degrees southward. It is probable that the sediments are still being actively folded.

The upper gravels are continuous with the Oxnard aquifers of Oxnard Plain Basin. The gravels are poorly sorted and consist of cobbles and pebbles of sandstone, conglomerate, and igneous rock. They occur in a matrix of medium to coarse sand and contain small, irregular beds of silt and clay. Oxnard Forebay Basin is the apex of the large Oxnard Plain alluvial fan where the coarser materials are found. The nature of the clay capping the oxnard aquifer in Oxnard Plain Basin as it approaches Oxnard Forebay Basin is rather complex, as might be expected. In general, the clay cap interfingers with the gravels of the Forebay, the percentage of clay decreasing to zero in the Forebay. The bottom and top of the clay cap also slope downward away from the Forebay. As a result of the slope of the bottom of the cap and the interfingering with gravels, the actual contact of the free water surface with the clay cap will vary over a wide zone depending on the water levels in the Forebay.

The San Pedro formation underlies the alluvium unconformably, as shown in Section K-K', Plate 12-B, but appears to become conformable near the south and west edges of Oxnard Forebay Basin. A medium to coarse grained sand is found near or at the base of the San Pedro formation. This sand is the equivalent of the Fox Canyon member in West Las Posas Basin. The surface outcrop of the Fox Canyon member on the south slope of South Mountain continues westward into Oxnard Forebay Basin. Its outline beneath the alluvium has been traced by the use of water and oil well logs and by inspection of materials from wells drilled during this investigation. The probable extent of the Fox Canyon member is shown on the geologic map (Plate B-1B). The Fox Canyon is folded into a westward plunging anticline, the anticlinal structure of which is confirmed by deeper oil well logs. A few oil well logs indicate that the Fox Canyon member of the San Pedro formation



continuous into and beneath Oxnard Plain Basin, although areas of low permeability may exist which could retard flow of water toward Oxnard Plain Basin.

The nature of the San Pedro formation above the Fox Canyon member and how the upper Pleistocene alluvium is not well known. Available oil well logs indicate that other permeable beds exist above the Fox Canyon member and possibly underlie unconformably the alluvial gravels of the Forebay. These aquifers in the San Pedro formation cannot be traced by well logs into Mound Basin, but there may be some continuous beds since water levels can be contoured into Mound Basin from the west end of Oxnard Forebay Basin.

The oldest formation of interest is the Santa Barbara formation of lower Pleistocene and upper Pliocene age which consists of impervious clay and silt. This formation underlies the San Pedro formation and both have been folded and partially removed by erosion in Oxnard Forebay Basin prior to deposition of alluvium. As a result of this folding and erosion, the Santa Barbara formation lies immediately under the alluvium in the area between the Saticoy spreading grounds and the westernmost exposures of the formation on Oak Ridge. Several well logs indicate that the depth to the eroded surface of the Santa Barbara formation averages about 75 feet but ranges up to 140 feet.

The Saticoy fault separates Oxnard Forebay Basin from Santa Paula Basin. The exact location of the fault beneath the Santa Clara River east of Saticoy is unknown, hence the boundary there is arbitrary, but is guided by the point where surface water from Santa Paula Basin begins to percolate into the river gravels. The boundary between Oxnard Forebay Basin and Mound Basin is also somewhat arbitrary and has been placed along the north edge of the Santa Clara River, where well logs indicate the approximate limit of the permeable gravels of the alluvium. The boundary between Oxnard Forebay Basin and Oxnard Plain Basin has been established from well logs and is the probable limit of the area where rainfall penetration and excess applied irrigation water returns to the aquifer. This does not

necessarily coincide with the actual pressure-nonpressure boundary which has been discussed above.

Occurrence of Ground Water. Ground water occurs in the Recent and upper Pleistocene alluvium and in permeable sands and gravels of the San Pedro formation. Oxnard Forebay Basin is essentially a free ground water area, with changes of water level and corresponding changes in ground water storage occurring in the alluvium. Apparently, the permeable zones in the San Pedro formation underlie and are in hydrologic continuity with the alluvium. The Santa Barbara formation underlying the San Pedro consists of fine silt and clay and is generally impervious.

Movement of Ground Water. Ground water moves southwesterly in Oxnard Forebay Basin toward Oxnard Plain Basin as shown on the water level contour maps (see Plates 14-B, 15-B, and 16-B). The shape of the water table contours in the upper portion of the Forebay resemble those of a ground water mound produced by an injection well. The Saticoy fault and the eastern boundary of Oxnard Plain Basin near the Forebay may be visualized as enclosing a segment of a circle. Slope of the water table decreases away from the apex in much the same way the hydraulic gradient decreases away from an injection well. A difference in elevation of 50 to 100 feet occurs across the Saticoy fault in a distance as short as 500 feet.

Movement of water into Oxnard Plain Basin may be complex when water levels in Oxnard Forebay Basin are low. For example, when the westerly end of the Forebay has been lowered greatly by pumping, some water may leave the upper part of the Forebay, where water levels are high, and move into the area just south of the spreading ground, then back into the Forebay in the vicinity of the junction of Highways 101 and 101A.

### Replenishment and Depletion of Ground Water. Oxnard Forebay Basin is

replenished by subsurface inflow, by percolation in the Santa Clara River channel and in the Saticoy spreading grounds, and by percolation of direct precipitation and the unconsumed portion of water applied for irrigation and other uses. The forebay is depleted by subsurface outflow, pumped extractions, and probably by effluent discharge over the clay cap and consuptive use of phreatophytes during periods of high water level.

### Subsurface Inflow and Outflow. Subsurface inflow occurs from Santa

aula Basin through and possibly over the Saticoy fault. Some subsurface inflow may occur from Mound Basin when water levels there are higher than in the Forebay. Subsurface outflow occurs into Oxnard Plain Basin through the aquifers of the alluvium and San Pedro formation. Subsurface outflow into Pleasant Valley Basin possibly occurs through the aquifers of the San Pedro formation, primarily through the Fox Canyon member. Some subsurface outflow into Mound Basin probably occurs at various times through the San Pedro formation in the area near Montalvo. When water levels in the Forebay are above the clay cap of Oxnard Plain Basin, some subsurface outflow may occur into the semi-perched zone overlying the clay cap.

### Ground Water Storage Capacity and Specific Yield. Estimated changes of

storage in Oxnard Forebay Basin are discussed in Chapter II. Estimated weighted mean specific yield of sediments between the interval of the 1944 and 1951 water levels is 16 per cent. Estimated total storage capacity of the alluvium in Oxnard Forebay Basin is about 300,000 acre-feet. When water levels are lowered in Oxnard Forebay Basin, water levels also drop in Oxnard Plain Basin. If water levels were drawn down so the Oxnard aquifers were entirely dewatered, then total storage of the Oxnard aquifer in Oxnard Plain and Oxnard Forebay Basins is probably on the order of 800,000 acre-feet.



Yield of Wells. Irrigation wells in the Oxnard Forebay Basin yield from 200 to 2,000 gallons per minute, the average being of about 1,100 gallons per minute. Specific capacity of wells averages about 200.

#### Oxnard Plain Basin

The Oxnard Plain Basin ranges from sea level to about 100 feet in elevation, and occupies an area of about 46,460 acres. Included in the basin is about one-fourth of the irrigated area of Ventura County. This basin is bounded on the west by the Pacific Ocean, on the north by Mound Basin, and on the east by West Las Posas and Pleasant Valley Basins. The boundary between Oxnard Plain and Mound Basins is arbitrarily placed along the Santa Clara River.

Geology. Water-bearing formations in Oxnard Plain Basin include alluvium of Recent and upper Pleistocene age, the San Pedro formation of lower Pleistocene age, and to a minor extent the Santa Barbara formation of lower Pleistocene and upper Pliocene age. Formations underlying the Santa Barbara are penetrated only by oil wells and include the Pico, "Santa Margarita", Modelo, Topanga, and Sespe formations as well as volcanic rocks of Miocene age.

The principal aquifers underlying Oxnard Plain Basin are shown on Geologic Sections K-K' and M-M', Plate 12-B. The most important aquifer underlying Oxnard Plain Basin is the Oxnard aquifer, which is part of the upper Pleistocene alluvium. The Oxnard aquifer is a series of river deposited gravels and is continuous with gravels in Oxnard Forebay Basin. The east and northwest boundaries of Oxnard Plain Basin coincide with the extent of the Oxnard aquifer. The Oxnard aquifer is characterized by medium to coarse gravel interbedded with lenticular deposits of coarse sand and some clay streaks. Well logs indicate considerable irregularity in areal extent and thickness of clay and sand lenses, as would be expected of river deposits. The Oxnard aquifer is capped by yellow

ad blue clay and silt, the base of which ranges in elevation from sea level near the forebay to about 130 feet below sea level near the coast. The overlying clay cap varies from 50 to 150 feet in thickness, and well logs indicate that it contains lenticular sands and gravels, which causes some increase in permeability of the cap.

The clay cap is overlain by up to 50 feet of sand and gravel, which extends to the ground surface. These permeable sediments contain semi-perched ground water and are considered to be of Recent age.

The boundary between Oxnard Forebay and Oxnard Plain Basins is placed, as noted above, to include in Oxnard Plain Basin the area where applied water does not return to the principal aquifers. As also stated, above, the pressure-impregnation line coincides with the intersection of the unconfined water table with the base of the confining clay cap, which intersection shifts laterally as water levels in Oxnard Forebay Basin fluctuate.

The base of the Oxnard aquifer is rather poorly defined since most water wells do not penetrate more than a foot or two of clay below the gravel. In some cases, this basal clay may be only five or six feet thick and additional gravels may be beneath. In general, however, the Oxnard aquifer is about 75 to 20 feet in thickness, and the base varies in elevation from 180 feet to 250 feet below sea level.

Well log control of the sediments below the Oxnard aquifer is poor. Available logs indicate that the base of the upper Pleistocene sediments is about 10 to 500 feet below the surface (about 200 to 300 feet below the Oxnard aquifer) and that other aquifers of unknown areal extent and hydrologic continuity exist. In the southeast portion of Oxnard Plain Basin, a fairly continuous gravel stratum about 70 feet in thickness occurs at depths of 400 feet and extends at

least partly into Pleasant Valley Basin. Scattered well logs in other parts of Oxnard Plain Basin also indicate gravels at this depth. Near the City of Port Hueneme, however, a 600 foot water well penetrated only fine silt and clay from 300 to 600 feet, indicating that the 400 foot gravels do not underlie the entire Oxnard Plain Basin.

The Recent and upper Pleistocene alluvium is underlain by the San Pedro formation which varies from about 600 feet in thickness in the southern part of the Oxnard Plain to about 1,800 feet just south of the Santa Clara River. Only two water wells on the Oxnard Plain are known to completely penetrate the San Pedro formation. Several oil wells also penetrate it, but logs of these wells are generally poor. From a study of the available oil well logs, electric logs, and water well logs, it appears that the basal 100 to 300 feet of the San Pedro formation consists of sand and some gravel which is most likely continuous with the Fox Canyon aquifer in Pleasant Valley and West Las Posas Basins and is a potentially important aquifer in Oxnard Plain Basin. Electric logs of oil wells in the Oxnard oil field, about four miles due east of the City of Oxnard, indicate that the Fox Canyon member consists of a series of sands containing irregular interbedded silt and clay layers. Fossils indicating shallow marine or lagoonal conditions of deposition have been found in the few wells which have been inspected by geologists during drilling. Oil well logs suggest a thickening of the Fox Canyon northward toward the Santa Clara River, but it is extremely difficult to determine whether this member continues into Mound Basin. Some electric logs suggest that the basal part of the San Pedro formation near the Santa Clara River may contain water of poor quality. All sources of information indicate that sands and gravels occur in the San Pedro formation above the basal Fox Canyon member. The degree of hydrologic continuity of these additional pervious zones with areas of recharge, or with the Fox Canyon member, cannot presently be determined.



The Santa Barbara formation underlies the San Pedro formation in the Oxnard Plain and varies from about 2,000 feet in thickness near the Santa Clara River to about 800 feet in the southern part of the area. Electric logs of two water wells near Port Hueneme and Mugu Lagoon indicate that thick permeable zones exist here and also that the lower half or two-thirds of the formation probably contains water of poor quality. Electric logs in the Oxnard oil field area indicate fairly fresh or slightly brackish water in the formation, while electric logs in the Santa Clara River area indicate that nearly all the Santa Barbara probably contains water of poor quality. These electric logs also indicate that the Santa Barbara formation contains few permeable zones near the Oxnard oil field and the Santa Clara River areas. The outcrop of the Santa Barbara formation on the south slope of Oak Ridge adjacent to this basin similarly contains few permeable zones.

Structure of Oxnard Plain Basin is relatively simple. The water-bearing materials are generally nearly flat lying, and are not known to be affected by faulting. Total thickness of alluvium and the San Pedro formation south of the Santa Clara River is about 2,000 feet, while north of the river in the Santa Clara River syncline the total thickness is over 4,000 feet. See Geologic Section B-B", Plate B-1B, for structure of the area.

#### Seaward Extension and Hydraulic Continuity of Aquifers With the Ocean.

The relationship of the Oxnard and Fox Canyon aquifers with the offshore topography and geology is of considerable interest in arriving at an understanding of the ground water hydrology of Oxnard Plain, Oxnard Forebay, and Pleasant Valley Basins. The pertinent submarine topographic features are discussed in Chapter B.I and are shown on Plate B-3.

It is apparent that both the Oxnard and Fox Canyon aquifers extend for some unknown distance seaward beneath the ocean as illustrated by Geologic Sections K-K' and M-M' on Plate 12-B.

The seaward extension of the aquifers presents two important problems in the consideration of the ground water hydrology of the Oxnard Plain Basin. While data are lacking in many respects, the operation of the ground water basins is partly dependent on the conditions seaward of the coastline. The two problems are that the aquifers may outcrop at some unknown distance seaward on the ocean floor resulting in hydraulic continuity of the ground water with sea water, and that the seaward extension of these aquifers may act as ground water storage reservoirs not inventoried in the hydrologic study whose utilization is dependent on the seaward distance of the outcrop.

Seaward extend of the Oxnard aquifer is unknown, though the presence of two sharply defined submarine canyons a short distance southerly of the coastline offers reasonable possibilities for the outcropping of the aquifer close to shore thereby limiting utilization of the storage capacity, at least in the vicinity of the canyons. Evidence suggesting that the Oxnard aquifer outcrops in the vicinity of the head of Hueneme Canyon includes the following: (1) the development of a landward gradient during periods of low water levels of the piezometric surface near Port Hueneme, the contours having a roughly circular shape with the canyon at the center, (2) historic reports of fresh water outflow in the Hueneme Canyon at times of high water levels, (3) fluctuations of water levels in wells corresponding to but lagging up to three hours behind tidal fluctuations, and (4) water quality indicating possible sea-water intrusion in 1951 near Port Hueneme. The only indications for seaward extension of the Oxnard aquifer or connection with the ocean in the vicinity of Mugu Canyon are a landward gradient in the ground water surface and a response to tidal fluctuations in the wells. These canyon outcrops, as shown on Plate B-3, may be within a quarter of a mile of the shoreline.

Well log control on the Fox Canyon aquifer of the San Pedro formation in the Oxnard Plain Basin is poor, but available data indicates that this aquifer thins southward, rising gently, so that it would be closer to the surface near Mugu

Canyon. It is possible that the Fox Canyon outcrops in both the submarine canyons, but available geologic evidence is not conclusive.

The offshore extensions of aquifers constitute additional ground water storage space, the volume of which is undeterminable at this time and has not been considered quantitatively in the hydrologic balances compiled in the course of this investigation. It is conceivable that such storage could be considerable. For purposes of speculation, the Oxnard aquifer was projected westward beneath the ocean as indicated on the sections of Plate B-3. Projection of the Oxnard aquifer to the ocean floor indicates that it would outcrop in the vicinity of the 120 to 140 foot depth contours as shown on Plate B-3. Postulating further from the geology of Oxnard Plain Basin it was estimated that the average thickness of the Oxnard aquifer offshore is about 100 feet and that the specific yield is about 10 per cent. The maximum area underlain by the offshore extension was estimated to be about 51,000 acres. These values are based upon assumptions that may be considerably in error; however, they conform with and are believed to be the most reasonable values that can be obtained with available information. An estimate of offshore storage based on these values indicates the Oxnard aquifer may contain up to 5,100,000 acre-feet of ground water. The possible capacities of offshore extensions of the Fox Canyon and other aquifers do not lend themselves even to such approximations. It is conceivable, however, that offshore storage in these aquifers can be great.

It is obvious that data are not available to determine accurately either the degree of hydraulic continuity with the ocean or the offshore storage capacity of the aquifers. Full utilization of offshore storage is improbable because of the outcrop of the aquifers within the submarine canyons. Wells situated in the vicinity of these canyons may become polluted by inflow through the canyon walls before offshore storage in more remote submarine areas is exhausted. Water levels



in the Oxnard Plain Basin should, therefore, be maintained at such levels as to prevent accumulative intrusion of sea water.

Occurrence of Ground Water. Ground water occurs in a semi-perched zone in the Oxnard aquifer which is the principal aquifer, in the Fox Canyon aquifer, and in less easily traced gravels between these aquifers. At the present time, only two wells in this basin obtain water from the Santa Barbara formation. The semi-perched zone is unconfined, has no wells withdrawing water from it, and contains water of poor quality. All aquifers underlying the semi-perched zone contain confined ground water. Wells along the coast in the Oxnard aquifer flowed prior to 1927 and during the period from 1942 to 1944. The area of flowing wells in the spring of 1944 is shown on Plate 15-B.

Movement of Ground Water. Movement of ground water in the Oxnard aquifer is shown by the ground water elevation contour maps (Plates 14-B, 15-B, and 16-B). When Oxnard Forebay Basin is filled as in 1944, water moves southwestward from the Forebay toward Hueneme and Mugu Canyons. When the water levels are lowered in the Forebay by pumping in Oxnard Plain and Oxnard Forebay Basins, the hydraulic gradient toward the ocean decreases until no outflow to the ocean occurs. Further pumping on Oxnard Plain Basin or further lowering of the Forebay causes landward hydraulic gradient with a resultant landward movement of water in the seaward extension of the aquifer. When the landward gradient occurs, a trough is formed. The formation of the trough will depend on elevation of the water table in Oxnard Forebay Basin and the amount of pumping in the Oxnard Plain Basin. Detailed water level contours indicate that the position of the trough axis approximates the shape of two circular segments with Hueneme and Mugu Canyons as center of the circles. The position of the trough axis varies seasonally as pumping rates and water levels in Oxnard Forebay Basin change. The trough position in the

fall of 1951 is shown on Plate 16-B, along with the area in which water levels were below sea level.

Movement of ground water in the Fox Canyon aquifer is not well known because few water wells are drilled into it and water level data are largely lacking. From available evidence it appears that water in the Fox Canyon aquifer moves from Oxnard Forebay Basin toward the southern portion of Oxnard Plain Basin. When pumping occurs in Pleasant Valley Basin, ground water in the Fox Canyon aquifer moves eastward from Oxnard Plain Basin into Pleasant Valley Basin, as shown on Plate 16-B.

In the southeast portion of Oxnard Plain Basin there are a few wells which are perforated in both the Oxnard and Fox Canyon aquifers, and water levels appear to be nearly the same in the two aquifers.

Replenishment and Depletion of Ground Water. Oxnard Plain Basin is replenished by subsurface inflow from Oxnard Forebay and from the ocean side of the trough during periods of low water levels. It is possible that a minor amount of water is supplied to the Oxnard aquifer during periods of low water level by compaction of overlying clays. Appreciable leakage may occur through the clay from the semi-perched zone into the Oxnard aquifer, but its amount could not be estimated because of the considerable time and expense required. No hydrologic evidence is available to show that leakage does occur through the clay cap, but well logs consistently indicate that this cap contains irregular interbedded lenses of gravel and sand, and it is therefore conceivable that leakage could occur.

Extractions from Oxnard Plain include pumping and, during periods of high water levels, outflow to the ocean and effluent discharge through uncapped wells. It is probable that some water is lost by leakage through the clay cap when the piezometric surface of the Oxnard aquifer is higher than the water table of the semi-perched ground water body.

It is also possible that an unknown amount of water is transferred between Oxnard Plain Basin and Mount Basin through the San Pedro formation.

Subsurface Inflow and Outflow. Subsurface inflow and outflow is discussed above.

Ground Water Storage Capacity. Since the aquifers in Oxnard Plain Basin are confined, there is essentially no change in storage except that resulting from compaction of overlying clays. Such change of storage is probably negligible. The base of the clay which caps the Oxnard aquifer in general slopes oceanward as shown on Geologic Section K-K', Plate 12-B, and the diagrammatic sketch on Plate 13. Therefore, the line of intersection of the water table with the base of the clay cap shifts laterally with varying water levels in Oxnard Forebay Basin resulting in change of storage in the area defined as Oxnard Plain Basin. For convenience, such change of storage has been included with that in Oxnard Forebay Basin.

It is estimated that the total storage capacity of that portion of the Oxnard aquifer within Oxnard Plain Basin, if it could be dewatered, would be about 500,000 acre-feet, and that the capacity of the Fox Canyon aquifer is probably the same.

Yield of Wells. Water wells in Oxnard Plain Basin yield from 300 to 2,300 gallons per minute and have an estimated average yield of about 900 gallons per minute and an average specific capacity of about 70.



## Pleasant Valley Basin

Pleasant Valley Basin has been divided in prior reports into pressure and non-pressure areas. It is considered in its entirety as a pressure area in this report for reasons discussed below. This basin consists of about 23,850 acres and is second only to Oxnard Plain Basin in irrigated acreage. It ranges in elevation from about 15 to over 240 feet above sea level.

Geology. Many aspects of the geology and ground water hydrology in Pleasant Valley Basin are not clearly understood; faulting, folding, rapid thinning of formations, multiple perforations of individual wells, and lack of adequate logging and inspection of wells during drilling make an interpretation of the geology of the area difficult.

The water-bearing formations in Pleasant Valley Basin include alluvium of Recent and upper Pleistocene age, and the marine San Pedro and Santa Barbara formations. These formations are underlain by the Pico and "Santa Margarita" formations, Modelo shale, and volcanics of Miocene age. The volcanic rocks outcrop in the Santa Monica Mountains on the southeast side of Pleasant Valley Basin.

In general, there are two areas in Pleasant Valley Basin where aquifers in alluvium of Recent and upper Pleistocene age are utilized. One area is north of the Camarillo fault and south of the Camarillo Hills, the other is south of the Camarillo fault in the east and southeast portion of the basin. The aquifers in these areas do not appear to be connected with the Oxnard aquifer in Oxnard Plain Basin. Alluvium north of the Camarillo fault reaches a thickness of 400 feet and consists of grey sand, gravel, and yellow and blue clay deposited in alluvial fans by Arroyo Las Posas and by other smaller creeks. The sands and gravels are thickest to the north and appear to pinch out toward the south. The alluvium south of the Camarillo fault is about 400 feet thick and is mostly clay with irregular interbedded sands and gravels. Sands and gravels are predominant in the easterly portion of Pleasant Valley Basin and appear to thin out westward.

from the area south of the town of Camarillo into the west central portion of this basin.

The San Pedro formation underlies all Pleasant Valley Basin and consists of from 400 to 1,500 feet of gravels, sands and clays. The most important aquifer in Pleasant Valley Basin is the basal Fox Canyon member which consists of sand and gravel. Thickness of the Fox Canyon aquifer varies from 100 feet near Santa Rosa Valley to 300 feet in most of the area. The Fox Canyon aquifer can be easily traced by well logs over all but the eastern corner of the basin, where there are few logs of deep wells. It is possible that the Fox Canyon aquifer is connected by interbedded gravels with the shallower sands and gravels of the alluvium in the eastern portion of Pleasant Valley.

The Fox Canyon aquifer is underlain by the Santa Barbara formation, which consists of sand, clay, and some gravel and varies in thickness from 50 feet near Somis to over 900 feet at the west border of the area. The Santa Barbara formation is reached by few water wells in Pleasant Valley Basin. It is possible that the equivalent of the Grimes Canyon member in East Las Posas Basin is present in Pleasant Valley Basin near the top of the Santa Barbara formation as shown on Geologic Sections L-L' and M-M', Plate 12-B. The Grimes Canyon aquifer consists of up to 300 feet of loose, coarse gravel and sand.

The volcanic rocks which are adjacent to and underlie the southern portion of Pleasant Valley Basin yield water to wells from fractures and from gravel interbedded with the volcanic flows. Most wells drilled into the volcanics also obtain water from overlying gravels of the alluvium or San Pedro formation.

Structural features of Pleasant Valley Basin include at least two east-west trending faults and associated folds in the northern portion of the area. The faults and folds appear to die out westward into the Oxnard Plain. These structural features are the Camarillo Hills and Springville anticlines, the Springville fault zone, the Camarillo fault, and a syncline and anticline between these faults.

The Springville fault zone (see Plate B-1B) is up to 1,000 feet wide and consists of two major and probably other minor faults which parallel the south edge of the Camarillo Hills. The major faults of this zone are well exposed in portions of the Camarillo Hills. Several exposures along one of these faults show that it in turn consists of a complex zone up to 100 feet wide with highly folded sediments included between lesser faults. The principal fracture occurs in a zone of crushed sediments varying from a foot to several feet in width.

The Camarillo fault can be detected in water well logs where displacement of aquifers may be noted. It also has effected older alluvium and can be traced by surficial features.

The folds between the Camarillo fault and the Springville fault zone consist of an east-west trending anticline just north of the Camarillo fault, and a syncline farther north. These folds can be traced from well log data and surface outcrops of older alluvium near Camarillo. The gentle synclinal fold between the Camarillo fault and the Santa Monica Mountains can be detected from well logs.

The Fox Canyon aquifer is folded in the Camarillo Hills anticline so that the top of it is exposed near Somis, as shown on Geologic Section L-L', Plate 12-B. The Fox Canyon aquifer is displaced by the Springville fault zone along the south side of the Camarillo Hills and also by the Camarillo fault. Well logs indicate that the Fox Canyon aquifer lies unconformably on the volcanic rocks along the south side of the Pleasant Valley Basin but does not outcrop there. It continues eastward, north of the Camarillo fault, into the Santa Rosa Basin where it pinches out.

Occurrence of Ground Water. Ground water occurs in sands and gravels of the alluvium and of the San Pedro formation, as well as in the fractured volcanics. Ground water in the basin is essentially confined. However, the Fox Canyon member is unconfined in a limited area near Somis. Some of the very shallow sands and



gravels around the north and southeast sides of the area may be unconfined, but available well logs indicate the shallow sands and gravels to be underlain by thick clays which probably prevent appreciable amounts of surface water from reaching the major aquifers.

Movement of Ground Water. Ground water moves toward the center of Pleasant Valley Basin during periods of heavy draft. When water levels are high the ground water generally moves in a southerly direction. Plates 14-B, 15-B, and 16-B show water level elevation contours of the two principal aquifers in this basin.

Replenishment and Depletion of Ground Water. Pleasant Valley Basin is replenished principally by subsurface inflow from East Las Posas Basin near Somis and from Oxnard Plain Basin through the Fox Canyon Aquifer. Replenishment of smaller magnitude also occurs by subsurface inflow from Santa Rosa Basin through the San Pedro formation, from West Las Posas Basin through the Springville fault zone, and from the volcanics to the south and southwest of the basin. Ground water from Pleasant Valley Basin is depleted by pumped extractions and possibly by subsurface outflow toward the ocean during periods of high water level.

Subsurface Inflow and Outflow. Nearly all ground water used in Pleasant Valley Basin is supplied by subsurface inflow from the following sources: (1) From the ocean and Oxnard Forebay Basin through the Fox Canyon aquifer under Oxnard Plain Basin; (2) From East and West Las Posas Basins through the Fox Canyon aquifer near Somis and across the Springville fault zone; (3) From Santa Rosa Valley through the San Pedro formation; (4) From the fractured volcanics into overlying and adjacent shallow aquifers and the Fox Canyon aquifer.

Subsurface outflow toward the ocean may occur during periods of high water level.

Ground Water Storage Capacity. Negligible change of storage occurs in the little used shallow sands and gravels and in the confined aquifers. It is likely that some change of storage has occurred in the volcanic rocks, but data are not available to make an estimate of this change. Similarly, data are lacking for an estimate of total storage capacity of the basin, although it is probably of the order of magnitude of the storage capacity of Oxnard Plain Basin.

Yield of Wells. In general, the wells which are perforated in the Fox Canyon aquifer yield the greatest amounts of water. The maximum is about 2,400 gallons per minute and the average about 1,000 gallons per minute with a drawdown of about 10 to 50 feet. Wells perforated in both volcanic rocks and shallower aquifers or in shallower aquifers only generally yield up to 1,000 gallons per minute, the average being about 400 gallons per minute and the drawdown 30 to 70 feet.

## Ground Water Basins Within the Calleguas-Conejo Hydrologic Unit

The ground water basins of the Calleguas-Conejo Hydrologic Unit include Simi, East and West Las Posas, Conejo, Tierra Rejada, and Santa Rosa Basins. Simi Basin is the only basin in this hydrologic unit which is essentially a simple alluvial filled type. The others are complex and consist of two or more formations which are folded and faulted. Geologic features of this unit are shown on Plate B-1C, and certain physical characteristics are summarized in Table 16 of Chapter II.

### Simi Basin

Simi Basin, comprising an area of about 10,760 acres, underlies the alluvial area of Simi Valley in the extreme east central portion of the Calleguas-Conejo Hydrologic Unit. The floor of Simi Valley is formed by coalescing alluvial fans emanating from Tapo Creek and other canyons. Surface elevation ranges from 700 feet at the western end of the valley to 1,100 feet near the apex of the Tapo Creek cone. A maximum surface elevation of 3,117 feet is attained on the drainage divide in the Santa Susana Mountains to the north.

Geology. Geologic formations in the Simi Valley area may be divided into permeable alluvium of Recent and Pleistocene age and older semi-permeable formations. The folded Santa Barbara formation forms a ground water basin in the Tapo Canyon area which is separated from the alluvial filled Simi Valley by semi-permeable older formations. Semi-permeable formations include the volcanics, Sespe, upper and lower Lajas, Santa Susana-Martinez, and sandstones of Cretaceous age. Of these semi-permeable formations, the Sespe, lower Lajas, and Cretaceous formations yield some water to wells in the hills on the south and southeast side of Simi Valley. Ground water in some of these formations appears to be of poor quality, especially at depths of more than 300 or 400 feet.



Alluvium in Simi Basin consists of stream deposited gravel, sand, and clay up to 730 feet thick. The base of the alluvium is bowl-shaped and tapers upward to its edges. It is underlain and flanked by the older formations mentioned above. The alluvium has a high clay content in the west end of the valley, where it locally confines the underlying gravels. Elsewhere in Simi Basin the clays are lenticular and quite irregular.

The older formations in the hills surrounding Simi Valley form a syncline which plunges gently westward. The syncline is cut off on the north side of the valley by the Simi fault.

In the Tapo Canyon area about three miles north of Simi Basin, the Santa Barbara formation of Plio-Pleistocene age is exposed. It consists of marine and continental gravels, sands, and clays, all of which have been folded into a tight syncline by southward thrusting of the Santa Susana fault. The Santa Barbara formation is over 1,000 feet thick in this area. Although some of the deep alluvium in Simi Basin may be equivalent to part of the Santa Barbara formation, the two are not in hydrologic continuity as they are separated by the semi-permeable formations north of Simi Valley.

Occurrence of Ground Water. Ground water occurs in the alluvial fill of Simi Valley and in interstices and fractures of the older formations that flank the valley. The alluvial fill constitutes the principal aquifer and underlies the area of Simi Basin. Second in importance is the isolated area of the Santa Barbara formation which yields water from permeable sand and gravel members in the vicinity of Tapo Canyon.

In cross-section the alluvium of Simi Basin is shown to be shallow near the perimeter of the basin and to increase in thickness toward the center (Sections Q-Q' and R-R', Plate 12-C) where it exceeds 700 feet.

Near the westerly extremity of the valley the alluvium at shallow depth contains considerable clay and silt. These fine materials serve to locally

confine ground water. In periods of high water level, wells that penetrate beneath these materials have flowed. However, unconfined conditions predominate in Simi Basin.

Movement of Ground Water. Ground water in the alluvium of Simi Valley moves westerly except in dry periods when wells are heavily pumped (see Plates 14-C, 15-C, and 16-C). During such periods a depression forms in the central portion of the basin and the ground water converges on this low area.

Ground water in the older semi-permeable formations moves in general toward the valley fill. In the eastern portion of Simi Valley water levels in wells in alluvium are generally lower than water levels in wells perforated only in the underlying older formations.

Replenishment and Depletion of Ground Water. Ground water in Simi Basin is replenished by percolation of direct precipitation, stream flow, and the unconsumed portion of water applied for irrigation and other uses. Additional sources of replenishment are artificial spreading and a minor amount of subsurface inflow from older formations. Ground water in the older semi-permeable formations and in the Santa Barbara formation in the Tapo Canyon area is replenished by rainfall penetration and stream percolation.

The alluvial basin is depleted by pumped extractions, consumptive use of phreatophytes, effluent discharge and subsurface outflow. The semi-permeable formations are depleted by evapo-transpiration, pumping, by outflow through springs during periods of high water level, and by subsurface outflow into the alluvium. The Santa Barbara formation is depleted by spring discharge and by pumping of water for export to Simi Valley.

Subsurface Inflow and Outflow. Subsurface inflow enters the alluvial fill of Simi Basin from adjacent older formations, but no subsurface inflow is known to enter this hydrologic subunit from other subunits. Subsurface outflow

aves Simi Valley through the Arroyo Simi where the alluvium appears to be only 6 to 100 feet thick and about 1,000 feet wide, and enters East Las Posas Basin. Subsurface flow out of Simi Valley through this alluvium has been estimated by the slope-area method to be about 100 acre-feet per year. During periods of low water levels, it is possible that subsurface outflow becomes negligible.

Ground Water Storage Capacity and Specific Yield. Estimates of change of storage in the alluvium of Simi Basin are discussed in Chapter II. Estimated weighted mean specific yield of alluvial sediments in Simi Basin is 8.6 per cent. Total storage capacity of the alluvium below high water level of 1929 was estimated to be about 180,000 acre-feet. Storage above this level was estimated to be about 40,000 acre-feet.

Yield of Wells. Wells in the alluvium of Simi Valley yield an average of about 400 gallons per minute. An exceptional well in Cretaceous sandstone is reported to yield 1,200 gallons per minute, but most of the wells in the older rocks yield about 100 gallons per minute. Wells in the Santa Barbara formation in the Tapo Canyon area have an average yield of about 100 gallons per minute.

Artificial Spreading of Water as a Means of Basin Replenishment. Studies of the Soil Conservation Service and the Division of Water Resources indicate the most suitable locations for major spreading works on alluvium are situated near the mouth of Tapo Canyon, along Chivo Creek and along Arroyo Simi just west of Santa Susana. The Tapo Creek location provides greater available ground water storage than does the Arroyo Simi location, but infiltration rates at this site are inferior. The Chivo Creek area appears to have least available storage but infiltration rates are suitable. Before any particular site is chosen here or in any other area for large scale spreading, exploratory test wells should be drilled and pilot spreading operations conducted to insure success.



## East Las Posas Basin

East and West Las Posas Basins are geologically similar in some respect but differences are great enough that they can be described separately. East Las Posas Basin comprises about 36,370 acres and is located within the East Las Posas subunit. It is bounded by nonwater-bearing formations which are adjacent to the basin on the south slope of Oak Ridge, in the Happy Camp Canyon area, and in the Las Posas Hills. The western boundary is the surface drainage divide between East and West Las Posas Basins. Near Somis the boundary was arbitrarily placed across the narrowest part of the southwesterly-trending valley through that town. Elevation of the drainage area ranges from about 250 feet near Somis to about 2,800 feet on Oak Ridge.

Geology. East Las Posas Basin is a broad east-west trending valley between Oak Ridge and the hills on the south and is presently undergoing stream dissection. The principal water-bearing materials of the basin are Recent and upper Pleistocene alluvium and the San Pedro and Santa Barbara formations. Semi-permeable older formations adjacent to and underlying the water-bearing formations include the Sespe, Vaqueros, Modelo, and Pico formations, as well as limited areas of volcanic rocks. Most of these older formations contain water of poor quality but good water has been obtained from sandstones and conglomerates of the Sespe formation. Late Quaternary alluvium occurs as fill in most of the valleys of the basin. The thickest, most extensive, and most important alluviated area is in the vicinity of Moorpark, where the alluvium consists principally of up to 200 feet of sand and gravel and underlies about 5,100 acres. Near Somis the alluvium is only 40 to 80 feet thick, and consists of silts and clays. In the smaller valleys, alluvium generally varies up to 40 feet in thickness and consists of silt and sand with some clay and gravel.

Previous workers have called the youngest of the pre-alluvial sediments "terrace deposits". Since most of these deposits are folded and since it is extremely difficult to differentiate them from the underlying San Pedro formation they are considered in this report as part of the San Pedro formation. The San Pedro formation is up to 2,000 feet thick in this basin and consists predominantly of yellow, red, and blue silty clay, with lenticular sands and gravels.

The San Pedro formation contains two members notable as aquifers; namely the Epworth gravels and the Fox Canyon aquifer. The Epworth gravels, near the top of the San Pedro formation, are located in a rather limited area lying about two to three miles north and northwest of Moorpark. They consist of up to 200 feet of gravel, gravelly clay, and silt, grading westward and southward into silt and clay. The Epworth gravels are probably remnants of an ancient alluvial fan, which accounts for their limited extent. The gravels have been folded and partially eroded so that they now outcrop in the area shown on the geologic map (Plate B-1C) and they underlie a total area of about six square miles.

The basal Fox Canyon member of the San Pedro formation has been named from its excellent exposure in Fox Canyon, about a mile west of Bradley Road. It consists of from 100 to 400 feet of sand and gravel containing some clay and silt lenses. The outcrop of the Fox Canyon member along the south slope of Oak Ridge is irregularly bedded as a result of facies changes and scour and fill, and varies considerably in total thickness. Fossils found in the member indicate deposition under shallow marine conditions. Sediments of the Fox Canyon member generally are white or gray in color. These sediments can be easily differentiated on the outcrop from the underlying Grimes Canyon sediments because of the distinct brown coloring of the latter. In well logs it is usually difficult to differentiate Fox and Grimes Canyon sediments. From a study of all available logs it is clear that the Fox Canyon aquifer extends under most of East Las Posas Basin. In general, the Fox Canyon aquifer is thickest in the central portion of the basin where

it consists principally of coarse sand. On Oak Ridge it is variable in thickness and consists of gravel and sand grading into fine sand near Happy Camp Canyon, where it pinches out entirely. On the Las Posas Hills it consist of sand and gravel, grading into sand near Moorpark.

In East Las Posas Basin, most of the San Pedro formation other than the above mentioned aquifers consists of fine silt and clay with scattered lenses of gravel and sand. Since individual gravel lenses are quite local, and since yield of wells in this material is generally quite low, this portion is here called the semi-permeable portion of the San Pedro formation. These materials overlies the Fox Canyon aquifer, and confine the ground water under pressure in that aquifer.

The Santa Barbara formation underlies the San Pedro formation and in this basin consists of up to 2,000 feet of clay, silt, sand, and gravel. At the west end of Oak Ridge it consists of clay and silt, but east of Bradley Road sand and gravel lenses become more common along the outcrop until in Happy Camp Canyon they predominate. The formation also thins to about 1,000 feet near Happy Camp Canyon. A coarse gravel member near the top of the Santa Barbara formation is exposed east and north of Bradley Road and is called the Grimes Canyon aquifer. This aquifer consists of coarse to fine brown gravel, sand, and lenses of clay and silt. The rusty brown color of the Grimes Canyon is usually distinctive, but occasionally is not evident in exposures or well logs. The aquifer varies in thickness from zero to about 1,000 feet in Happy Camp Canyon where it comprises nearly all the Santa Barbara formation. The Grimes Canyon aquifer underlies most of East Las Posas Basin.

The Grimes Canyon aquifer is overlain by the Fox Canyon aquifer, and several outcrops reveal them to be in direct contact, although a clay member within the Santa Barbara formation separates the two aquifers in other exposed areas. The thickness of the aquifers indicated by some water and oil well logs suggests that the Fox Canyon and Grimes Canyon aquifers are in direct contact under much, if not



most, of East Las Posas Basin. It is possible that some of the sediments of the Santa Barbara formation in Tapo Canyon are also the equivalent of the Grimes Canyon member. The detailed field work necessary to make such a discrimination was not undertaken in this investigation. The Santa Barbara formation with exception of the Grimes Canyon aquifer previously described is for the most part composed of materials of low permeability.

The San Pedro formation, Santa Barbara formation, and the underlying Peco, Modelo, Vaqueros, and Sespe formations are all folded and faulted, only alluvium being undisturbed. In general, East Las Posas Basin is a synclinal area, plunging gently westward, and includes several minor en echelon synclines and anticlines. Oak Ridge and the Las Posas Hills are major anticlinal uplifts. The folding of the area has resulted in the Fox Canyon and Grimes Canyon aquifers being buried quite deeply in the central portion of the basin and exposed around the edges. Structural features and relationships of various aquifers are shown on Geologic Section N-N' and P-P', Plate 12-C.

Occurrence of Ground Water. Ground water occurs in the sands and gravels of the alluvial deposits, in the Epworth gravels, and in the Fox Canyon and Grimes Canyon aquifers. Limited amounts of ground water occur in sands and gravel lenses in the semi-permeable portion of the San Pedro formation which overlies the Fox Canyon member. Limited supplies of water occur in the older semi-permeable formations and may be of poor quality.

Ground water in the alluvial deposits and in the Epworth gravels is essentially unconfined, although water level behavior in some wells indicate locally confined conditions. Ground water in the Fox Canyon and Grimes Canyon aquifers is confined by the overlying silts and clays. Ground water is unconfined in these aquifers, however, near their upturned edges which approximate the outcrop areas as shown on Plate B-1C.

Movement of Ground Water. Ground water in the alluvium near Moorpark generally moves westward toward Somis except during periods of low water level, when a pumping depression forms southwest of Moorpark. Ground water in the Epworth gravels appears to move in a southerly direction, indicating some movement from the Epworth gravels into the semi-permeable portion of the San Pedro formation.

Ground water in the Fox Canyon aquifer moves in a southwesterly direction from Happy Camp Canyon and the outcrop along the north side of East Las Posas Basin. Subsurface flow in the fall of 1951 as depicted by dashed ground water contours on Plate 16-C converges on the Somis area and moves into Pleasant Valley Basin. Meager historic data suggests that in periods of high water levels ground water in the Fox Canyon aquifer moves westward into West Las Posas Basin as well as into Pleasant Valley Basin. Water levels of fall 1951 indicate a ground water mound in the piezometric surface of the Fox Canyon aquifer near the west boundary of East Las Posas Basin.

Replenishment and Depletion of Ground Water. Ground water in East Las Posas Basin is replenished by percolation of direct precipitation, stream flow, and the unconsumed portion of water applied for irrigation and other uses in outcrop areas of aquifers, and possibly to some extent by subsurface inflow from older formations that surround the basin. Alluvium southwest of Moorpark along Arroyo Las Posas overlies the Fox Canyon aquifer where they are probably in hydrologic continuity. In the vicinity of Somis and Moorpark, studies of water level and the chemical character of ground water have led to the conclusion that ground water moves from the alluvium into the Fox Canyon aquifer.

East Las Posas Basin is depleted by pumped extractions from the Fox Canyon aquifer and by consumptive use of phreatophytes. Additional depletion is effected by subsurface outflow and export of water into West Las Posas Basin.

Springs are reported to have flowed near Somis in Arroyo Las Posas in the early 1900's which would indicate that in periods of high water levels the basin was to some extent depleted by effluent discharge.

Subsurface Inflow and Outflow. Subsurface inflow into East Las Posas Basin is limited to that coming from older rocks and about 100 acre-feet per year which enters from Simi Basin through alluvium. This latter increment of inflow has been described under the paragraph on inflow and outflow to Simi Basin. Subsurface outflow into Pleasant Valley Basin through the Fox Canyon aquifer is indicated by water level contours (Plates 14-C, 15-C, and 16-C). This outflow has been estimated by the slope area method to be on the order of 3,000 acre-feet per year. As previously mentioned, subsurface outflow to West Las Posas Basin has probably occurred in the past during periods of high ground water level.

Ground Water Storage Capacity and Specific Yield. Changes in ground water storage occurring within East Las Posas Basin during selected study periods were estimated following the procedures described in Chapter B-VI and are discussed in Chapter II. Total storage capacity of aquifers in the basin could not be estimated, but is probably very large.

Depth to water in the outcrop area of the Fox Canyon and Grimes Canyon aquifers on Oak Ridge was approximately 500 or 600 feet in 1951 and 1952, and therefore considerable available storage exists in these aquifers above the water table. The average specific yield of the Fox Canyon and Grimes Canyon aquifers is believed to vary between 10 and 20 per cent. Estimated specific yield of the Worth gravels is about six per cent; most of the remainder of the San Pedro formation, three per cent, and the alluvium in the Moorpark area, eight per cent.



Yield of Wells. Estimated average yield of wells in East Las Posas Basin is summarized below:

Alluvium	400 gallons per minute
Epworth Gravels	300    "    "    "
Fox Canyon and Grimes Canyon Aquifers	600    "    "    "
Semi-permeable portion of San Pedro formation	10    "    "    "

Artificial Spreading of Water as a Means of Basin Replenishment. Water could be spread artificially on any portion of the outcrop area of the Fox Canyon or Grimes Canyon aquifers and reach the water table. The most desirable spreading area for these aquifers is in Happy Camp Canyon about three miles north of Arroyo Simi. This locality has available surface area for construction of spreading grounds, high rates of percolation according to the Soil Conservation Service, and free access to the water table of the Grimes Canyon aquifer which is in hydrologic continuity with the Fox Canyon aquifer. In addition, the water table is about 50 feet below the surface in this area so that adequate ground water storage is available. A seismic survey of the spreading area by this Division indicates an absence of clay lenses within 30 to 60 feet of the surface. Most other areas of outcrop have limited surface area available for construction of spreading works.

Spreading into the Epworth gravels may be possible, but this would benefit only the wells in these gravels. A large surface area is available for construction of spreading works near the corner of Broadway and Moorpark Roads, about two miles north of Moorpark, but spreading rates are probably low.

Spreading into alluvium near Moorpark is feasible from percolation rate and surface area aspects. However, available storage of alluvium is probably small even when the alluvium is dewatered, and it might be filled by natural stream percolation of Arroyo Simi during wet periods.

## West Las Posas Basin

West Las Posas Basin is located within the corresponding subunit and comprises about 11,450 acres. Elevation of the subunit ranges from 200 feet to a maximum of 2,258 feet on South Mountain. Boundaries of West Las Posas Basin are the outcrop of the Fox Canyon aquifer on the north, the surface drainage divide to the east and south, and the limit of the Oxnard zone of Oxnard Plain and Oxnard Forebay Basins on the west.

Geology. Aquifers of significance in West Las Posas Basin include the Fox Canyon and Grimes Canyon. The upper semi-permeable portion of the San Pedro formation overlies the Fox Canyon aquifer and in turn is overlain by alluvium of recent and upper Pleistocene age. The alluvium is not easily differentiated from the silts and clays of the underlying San Pedro formation, but it is probably up to 200 or 300 feet thick. The alluvium consists of fine yellow silt and clay with scattered lenticular sands and gravels and has been deposited in alluvial fans by small streams draining Oak Ridge. The semi-permeable portion of the San Pedro formation consists of over 1,000 feet of yellow and blue silty clay and clay, with scattered lenticular sands and gravels.

The Fox Canyon aquifer consists of 200 to 300 feet of sand and gravel at the base of the San Pedro formation. The Fox Canyon aquifer continues into East Las Posas Basin, Oxnard Plain and Forebay Basins, and into the Camarillo Hills and Pleasant Valley Basin. The Fox Canyon aquifer outcrops on the south slope of Oak Ridge and in the east end of the Camarillo Hills.

The Fox Canyon aquifer is underlain by the Santa Barbara formation which contains the Grimes Canyon aquifer near its top. The Grimes Canyon aquifer does not outcrop in the West Las Posas Basin but underlies it as shown by electric logs and drillers logs. It consists of up to 300 feet of coarse gravel and sand. Well

logs indicate that a clay bed up to 600 feet thick lies between the Fox Canyon and Grimes Canyon aquifers in the Camarillo Hills (see Section L-L', Plate 12-B). A similar clay bed is found on the outcrop in East Las Posas Basin and it is likely that these two clay beds are of a similar origin. Field inspection of the clay bed in East Las Posas Basin shows that an erosional unconformity at the base of the Fox Canyon aquifer has resulted in direct contact of the Fox Canyon and Grimes Canyon aquifers where the clay has been eroded.

As in East Las Posas Basin, folding of the Fox Canyon has resulted in its being exposed on the edges of the basin and deeply buried in the middle. The most prominent folds are the Camarillo Hills anticline and the Las Posas syncline.

Occurrence of Ground Water. The Fox Canyon and Grimes Canyon aquifers are the principal sources of ground water in West Las Posas Basin. Some water is derived from sand and gravel zones of limited extent contained within the semi-permeable portion of the San Pedro formation. Ground water in the Fox Canyon and Grimes Canyon aquifers is confined except where these aquifers outcrop on the southern slopes of Oak Ridge and where they have been folded in the Camarillo Hills (see Section L-L', Plate 12-B).

Movement of Ground Water. Movement of ground water in 1951, as depicted by contours (Plate 16-C), was westerly in the Fox Canyon aquifer toward Oxnard Forebay Basin. Some ground water possibly moves southward across the Camarillo Hills, through the Springville fault zone, and into Pleasant Valley.

Replenishment and Depletion of Ground Water. West Las Posas Basin is replenished by percolation of direct precipitation and stream flow on the outcrop area of the Fox Canyon aquifer and possibly to some extent by subsurface inflow from East Las Posas Basin. The silty upper portion of the San Pedro formation and alluvium may in addition be replenished by percolation of the unconsumed portion of water applied for irrigation and other uses. West Las Posas Basin is depleted



by pumping from the Fox Canyon and other aquifers and by subsurface outflow.

Subsurface Inflow and Outflow. Subsurface flow into West Las Posas Basin probably occurs from East Las Posas Basin during periods of high water level. Subsurface outflow occurs into Oxnard Plain and Pleasant Valley Basins through the Fox Canyon aquifer. The outflow has been estimated by the slope area method to be on the order of 600 acre-feet per year into the Oxnard Plain Basin. Subsurface outflow probably occurs across the Springville fault zone into Pleasant Valley Basin, but no data are available to estimate the amount. Since the ground water divide in the piezometric surface of the Fox Canyon aquifer is located close to the surface divide, it is likely that subsurface outflow into East Las Posas Basin through that aquifer is negligible.

Ground Water Storage Capacity and Specific Yield. Change of ground water storage in West Las Posas Basin is discussed in Chapter II. Specific yield of the Fox Canyon aquifer is estimated by inspection to be about 15 to 20 per cent. Specific yield of the overlying San Pedro formation and the alluvium is estimated to be about three per cent.

Yield of Wells. Yield of wells in the Fox Canyon and Grimes Canyon aquifers averages about 600 gallons per minute. Wells in the semi-permeable portion of the San Pedro formation yield about ten gallons per minute.

Artificial Spreading. Artificial spreading on the outcrop area of the Fox Canyon aquifer is physically possible, as in East Las Posas Basin, although the rugged topography limits areas in which spreading works could be constructed.

#### Conejo Basin

Conejo Basin is located in the southern portion of the Calleguas-Conejo Hydrologic Unit as shown on Plate 11. The basin varies in elevation from about

600 feet to 2,300 feet except on the floor of Conejo Creek Canyon, the elevation of which is about 300 feet. Within the hydrologic unit most of the rocks including volcanics and consolidated sediments absorb and transmit water, but wells in these rocks generally yield small amounts of water. Since there are no areas which can be easily defined as ground water basins, the entire drainage area of about 28,930 acres is considered as the basin.

Geology. Most of Conejo Basin is an upland valley area which has drained eastward in the geologic past, possibly into Triunfo Creek. The ancestral drainage was subsequently captured by headward erosion of Conejo Creek, so that the area now drains into Santa Rosa Basin.

Geologic formations in Conejo Basin include alluvium, Modelo sandstone and shale, volcanic rocks, the Topanga formation, and limited exposures of the lower Llajas and Santa Susana-Martinez formations as well as some consolidated sediments of Cretaceous age. Alluvium of Recent and Pleistocene age occurs as valley fill in the Newbury Park and Thousand Oaks areas, on the floor of Conejo Creek Canyon, and as terrace deposits scattered throughout the basin. The alluvium is generally shallow, probably being only a few feet thick except in the valley fill areas where it attains a thickness of about 60 feet. The volcanic rocks, the Topanga formation, and the Modelo sandstones and shales are drilled by many wells in Conejo Basin. The limited outcrops of other formations are not generally drilled within the basin. All the aforementioned formations are described in Chapter B-III of this Appendix. All the formations with the exception of the alluvium are folded and faulted as shown on the geologic map (Plate B-1C).

Occurrence of Ground Water. Ground water occurs in the alluvium, in the fractures and weathered portions of the volcanic rocks and Modelo shales, and in pervious zones of the Modelo sandstone and Topanga formations. The ground water

surface conforms, in general, with the topography as shown on Plate 16-C and is essentially unconfined. Most wells in alluvial areas penetrate the alluvium completely and obtain water from underlying formations as well as from alluvium. At the time of this investigation no water wells were known to have penetrated very deeply into the older rocks. Scattered oil well logs indicate that such previous zones exist in the older rocks, but quality of water in them is uncertain.

Movement of Ground Water. Ground water from the periphery of the basin converges toward Conejo Creek as indicated by ground water contours on Plate 16-C. Perennial springs which are supplied by subsurface flow from Conejo Basin exist in the canyon of Conejo Creek.

Replenishment and Depletion. Ground water is replenished by percolation of direct precipitation and stream flow as is evidenced by a close relationship between water table and topography and fairly rapid recovery of water levels following rains. Replenishment also occurs by percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water is depleted by pumped extractions, by consumptive use of phreatophytes, by effluent discharge, and, most likely, by subsurface outflow.

Subsurface Inflow and Outflow. No subsurface inflow occurs into Conejo Basin. Subsurface outflow probably occurs into Santa Rosa Basin through the alluvial fill in Conejo Creek Canyon and through the volcanics. Subsurface outflow may also occur into Pleasant Valley Basin, through the volcanics. Subsurface outflow through volcanics appears to be possible because: 1. The volcanics dip toward Santa Rosa and Pleasant Valley Basins; 2. Water levels in Conejo Basin are higher than in the other basins; 3. The volcanics are permeable. A ground water divide may exist in the same general location as the drainage



divide but water level data are lacking to verify this possibility. If this were the case, subsurface flow into Pleasant Valley and Santa Rosa Basins through the volcanics would be negligible.

Water level measurements in the Thousand Oaks area indicate that a ground water divide exists near the drainage divide so that subsurface flow in or out of the Malibu Hydrologic Unit is probably negligible.

Storage Estimates. Change of storage does occur in Conejo Basin as evidenced by fluctuations of water levels and unconfined ground water conditions. Well log and historic water level data are lacking, however, and specific yield of the various formations in the basin is uncertain. For these reasons estimates of change in storage in Conejo Basin are not considered to be of sufficient accuracy for use in the hydrologic balance.

Yield of Wells. Because of the general low permeability of the formations in Conejo Basin, average yield of wells is low and on the order of 50 gallons per minute. One exceptional well, however, yields 1,000 gallons per minute and several yield about 300 gallons per minute.

Artificial Spreading. Artificial spreading in Conejo Basin does not appear to be feasible because of relatively shallow depths to water and the general low specific yield of the formations.

#### Tierra Rejada Basin

Tierra Rejada Basin is located between Simi, Conejo, Santa Rosa, and East Las Posas Basins as indicated on Plate 11. Surface elevation ranges from 60 feet in the valley floor to about 1,600 feet on the drainage divide. Nearly all Tierra Rejada Basin is underlain by water-bearing volcanic rocks. For this reason the drainage divide is taken as the basin boundary. The basin includes an area of about 4,390 acres.

Geology. Although most of Tierra Rejada Basin is underlain by fractured volcanic rocks, a small portion is underlain by the Modelo, Topanga, and Sespe formations. The volcanics consist of about 2,000 feet of basaltic flows, agglomerates, rhyolitic tuffs, and interbedded conglomerates and clays. These materials are intruded by basaltic dikes and sills.

All formations present are folded and faulted. In general the structure of the basin is that of a westward plunging syncline. The volcanic rocks in the southern and eastern parts of the basin dip from 10 to 30 degrees toward the flat irrigated portion of the basin. North of the irrigated area the attitude of the volcanic rocks is nearly vertical. These rocks are terminated near the north boundary of the basin by the east-west trending Simi fault. Another fault trending north-south displaces the volcanic rocks several hundred feet near the western side of the basin.

Occurrence of Ground Water. The volcanic rocks are generally highly fractured but appear to be most intensively fractured beneath the irrigated portion of the basin, as wells in the volcanics have highest yields there. Ground water occurs chiefly within these fractures, and is essentially unconfined.

Movement of Ground Water. Ground water moves through the highly fractured volcanic rocks converging toward the westerly end of the basin. At the west end subsurface flow out of the basin is impeded by the above mentioned north-south fault. That this fault serves as a ground water barrier is evidenced by a pronounced drop in water level. In 1951 the ground water level east of this fault in Tierra Rejada Basin stood about 100 feet above the level observed in a well situated near the fault on its westerly side. Movement of ground water is indicated by ground water elevation contours on Plates 15-C and 16-C.

Replenishment and Depletion of Ground Water. Tierra Rejada Basin is replenished by percolation of direct precipitation, stream flow, and the unconsumed

portion of water applied for irrigation and other uses. The basin is depleted by pumped extraction, limited subsurface outflow into Santa Rosa Basin, and possibly effluent discharge and consumptive use of phreatophytes during periods of high water level.

Subsurface Inflow and Outflow. No subsurface flow enters Tierra Rejada Basin from Simi Basin. Water level measurements in the area of the drainage divide separating these basins indicates that a ground water divide exists which would prevent inflow from Simi Basin through the volcanics. If no ground water divide existed there, some inflow might be expected since water level elevations in the west portion of Tierra Rejada Basin are generally lower than in Simi Valley.

As previously discussed, the north-south fault at the west end of Tierra Rejada Basin limits subsurface outflow. A producing well situated a short distance west of the fault suggests that this fault is only a partial barrier since the only feasible source of supply is subsurface flow across the fault. It is likely that subsurface flow northward across Simi fault into East Las Posas Basin is negligible.

Ground Water Storage Capacity. As in Conejo Basin, poor geologic and hydrologic data resulted in uncertainties in change of storage estimates; so direct evaluation thereof could not be made.

Yield of Wells. Wells in Tierra Rejada Basin yield from 10 to 700 gallons per minute with an average yield in the principal pumping area of about 300 gallons per minute.

#### Santa Rosa Basin

Santa Rosa Basin, comprising about 3,490 acres, is located just east of Pleasant Valley Basin. It is bounded by the volcanics on the south, the limit of the San Pedro formation on the north, Tierra Rejada Basin on the east, and the



topographic narrows at the west end of the basin. Santa Rosa Basin ranges from 20 to over 400 feet in elevation with a maximum elevation of about 1,200 feet on the drainage divide.

Geology. Principal water-bearing sediments in Santa Rosa Basin include Recent alluvium and the San Pedro formation. Formations underlying and adjacent to the basin include the Santa Barbara, the Topanga and Sespe formations, and volcanic rocks.

Recent alluvium in Santa Rosa Basin consists of up to 200 feet of gravel, sand and clay. Fossil remains in outcrops of alluvium in the stream cut gullies indicate that some of the clays in the west end of the basin have been deposited in a fresh water swamp or shallow lake.

The San Pedro formation consists of up to 700 feet of gravel, sand, silt, and clay. In the western end of the basin a sand and gravel member about 100 feet thick can be traced in well logs at the base of the formation and is probably the equivalent of the Fox Canyon aquifer. This aquifer, however, cannot be traced in well logs into the central and eastern portion of the basin. In general, the sands and gravels of the San Pedro formation are extremely lenticular and with the above mentioned exception cannot be correlated between wells. In the west end of the basin, the Santa Barbara formation is found below the San Pedro, but it contains water of poor quality. Only one or two wells are drilled into it here, so that its structure is poorly known, but it apparently consists of silt and clay with lenticular gravels and sands. The volcanics of Miocene age which underlie the alluvium and San Pedro formation on the south side of the basin are exposed in the hills to the south where they dip ten to twenty-five degrees northward. The volcanics consist of over 2,000 feet of interbedded basaltic agglomerates and flows with scattered andesitic intrusions, all of which are fractured. The great thickness of volcanics on the south of the basin is represented in the Las Posas Hills by a basaltic

sill about 15 feet thick. Relationships of the formations are shown on Geologic Sections N-N' and P-P' on Plate 12-C.

All these formations except the alluvium have been folded and faulted. The structure of most significance is the east-west trending Santa Rosa syncline shown on the geologic map (Plate B-1C), in which the San Pedro formation has been folded. Field inspection of outcrops and well logs indicates that the north dipping flank of the syncline lies beneath the alluvium on the south side of Santa Rosa Basin. The San Pedro formation and alluvium are underlain in part by volcanics and other formations. The north flank of the folded San Pedro formation has been cut off by the Simi-Santa Rosa fault system, exposing the semi-permeable Sespe and Topanga formations in the Las Posas Hills just north of the basin.

Occurrence of Ground Water. Ground water occurs in pervious zones of the Recent alluvium and San Pedro formation and in the fractured volcanics. Water of poor quality occurs in the Santa Barbara formation and possibly in the Sespe and Topanga formations. Ground water in Santa Rosa Basin is essentially unconfined, although the pervious lenses of the San Pedro formation are confined in some areas.

Movement of Ground Water. Ground water in Santa Rosa Basin moves westerly and within the basin appears to move northerly from the volcanics and southerly in the San Pedro formation. Plate 16-C shows the southerly movement in the fall of 1951, but the northern direction of movement at this time was not appreciable. When Conejo Creek flows into Santa Rosa Basin, percolation occurs and a ground water mound is built up near the mouth of Conejo Creek. Past measurement of a well on the extreme south side of the basin as well as the presence of springs in the volcanics indicate that some water probably moves directly from the volcanics into the alluvium.

Replenishment and Depletion of Ground Water. Ground water in Santa Rosa Basin is replenished by percolation of direct precipitation, stream flow, and the unconsumed portion of water applied for irrigation and other uses as well as subsurface inflow. The basin is depleted by pumped extractions, subsurface outflow, and by effluent discharge and consumptive use of phreatophytes during periods of high water level.

Subsurface Inflow and Outflow. Subsurface inflow to Santa Rosa Basin occurs from Tierra Rejada and Conejo Basins. Inflow from both these sources is difficult to estimate by geologic methods because of the lack of wells and other data. Subsurface outflow into Pleasant Valley through the San Pedro formation has been estimated by the slope-area method to be about 200 acre-feet per year.

Ground Water Storage Capacity and Specific Yield. Estimates of change of storage in alluvium and San Pedro formation are discussed in Chapter II. Weighted average specific yield of the alluvium and San Pedro formation is estimated to be five per cent.

Yield of Wells. Water wells in Santa Rosa Basin yield up to 1,200 gallons per minute. Their yield averages about 600 gallons per minute, and specific capacities range from 10 to 30. The highest yielding well is in the volcanics, and wells in the San Pedro formation generally yield slightly less than those in the alluvium. In general, these differences are controlled by permeability, but in some instances are dependent on the method of well construction.

Artificial Spreading. Spreading in Santa Rosa Basin is feasible near the mouth of Conejo Creek, where most stream percolation has occurred. In the other areas where surface conditions appear suitable for spreading, well log data are poor, and it is not known whether large quantities of water would percolate directly to the water table.



## Miscellaneous Areas In and Near Ventura County

The areas discussed below are those which contain ground water bodies of unknown extent and usefulness within and adjacent to Ventura County, but which are outside the principal developed ground water areas.

### Malibu Hydrologic Unit

The Malibu Hydrologic Unit is located in the southeastern portion of the county and includes that portion of the Santa Monica Mountains draining southward to the ocean. Principal geologic features are shown on Plate B-1C.

Formations in this area include alluvium, Modelo sandstone and shale, volcanic rocks, the Topanga formation, and a small area of older sedimentary rocks. Ground water is obtained from wells drilled into most of these formations. Principal water-bearing formations, however, are the alluvium and the volcanic rocks.

Alluvium of Recent and Pleistocene age occurs as valley fill up to at least 100 feet thick in the upper drainage areas of Triunfo and Medea Creeks. The alluvial area which has most wells is Hidden Valley, located just west of Lake Sherwood. Water wells here penetrate alluvium and the underlying volcanic rocks. Nearly all the wells in Hidden Valley are used for domestic and limited irrigation purposes. Yield of wells is small in this area, probably averaging 50 gallons per minute. The low yield of the wells suggests that the alluvium and volcanics are fairly impervious and have low specific yield and storage capacity. The direction of movement of ground water is eastward toward Lake Sherwood as shown on Plate 16-C.

Downstream from Lake Sherwood a few irrigation wells obtain a good supply of ground water from the coarse alluvial gravels in the valley floor. In most of the remaining alluvial areas shown on the geologic map few wells have been drilled.

but the alluvium is most likely thin and probably does not contain large quantities of ground water.

Numerous wells have been drilled into the volcanic rocks, the Topanga formation, and the Modelo formation. Most of these wells yield small amounts of water, but one well in the volcanics and one in the Topanga formation reportedly yield 300 gallons per minute. Scattered well measurements and observations of springs in the Malibu Hydrologic Unit indicate that the ground water surface conforms in general with topography, as would be expected with formations of low permeability.

#### Rincon Subunit and Rincon Creek Drainage Area

The Rincon subunit is located along the ocean between the Ventura River and the Santa Barbara-Ventura County line. Ground water bodies are extremely small in this subunit, being restricted to the alluvial filled valley bottoms, the beach deposits, and the thin terrace deposits. Older formations probably contain water of poor quality, as do the beach deposits during dry periods. Because of the limited ground water bodies in the subunit only a few small wells are found there, most of the water being imported.

The geology and occurrence of ground water in the Rincon Creek area has been discussed by Upson (1951). Since Rincon Creek recharges a ground water basin located mostly in Santa Barbara County, the area will not be further discussed here.

#### Cuyama River Drainage Area

The principal development in the Cuyama River drainage area has occurred in Santa Barbara and San Luis Obispo Counties. This area has been described by Upson and Worts (1951). The following discussion applies principally to the Ventura County portion of the drainage area which is utilized by only a few wells.

Formations in the Ventura County portion of the Cuyama River drainage include alluvium, the Morales, Quatal, Simmler, and older sedimentary formations as well as granitic rocks. All of these are described in Chapter B-III of this appendix. The principal water-bearing formation presently utilized is alluvium of Recent and Pleistocene age which appears to be 60 to 100 feet thick in the valley areas. The morales and portions of the Quatal formations, although not presently utilized by wells, appear from surface lithology to be potentially good sources of ground water. Pronounced lowering of water levels may occur in the area if the ground water is utilized, because of low rainfall and probable limited recharge in the area of outcrop of the formations.

#### Upper Portions of Piru Creek Drainage

Areas in the upper portion of Piru Creek drainage where a few water wells are found include Lockwood Valley and Hungry and Peace Valleys. The latter two valleys are located in the alluvial areas shown on Plate 10 near the northeast corner of Ventura County.

In Lockwood Valley alluvium is very thin, and the few water wells in the area appear to be obtaining ground water from the continental sediments of Miocene age. One well in these sediments, however, had such a high boron content that a young apple orchard was destroyed by application of the water. The volume of ground water which is available for use is unknown, but is probably small.

In Hungry and Peace Valleys a few water wells obtain a supply from the relatively thin alluvium and from sand and gravel of the underlying Ridge Basin group of sediments of Pliocene age. Two wells in the upper part of the Ridge Basin group reportedly yield large amounts of water for irrigation purposes. It is not known whether ground water storage and recharge is sufficient for potential future irrigation uses.



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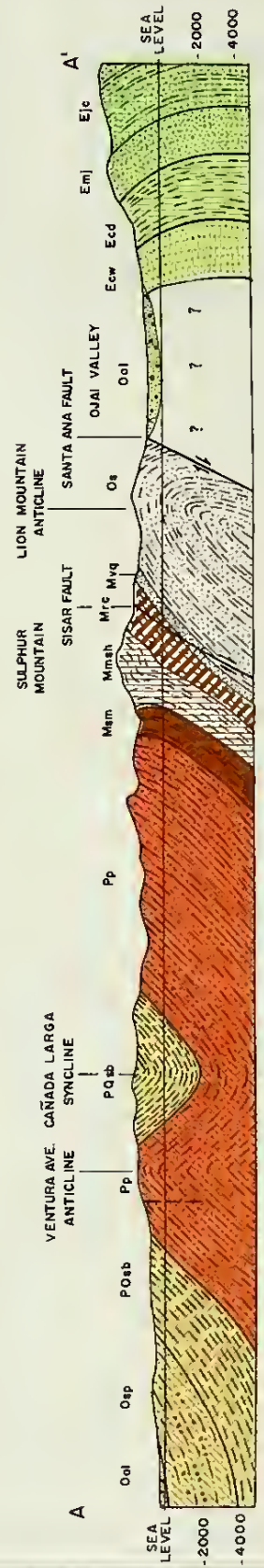
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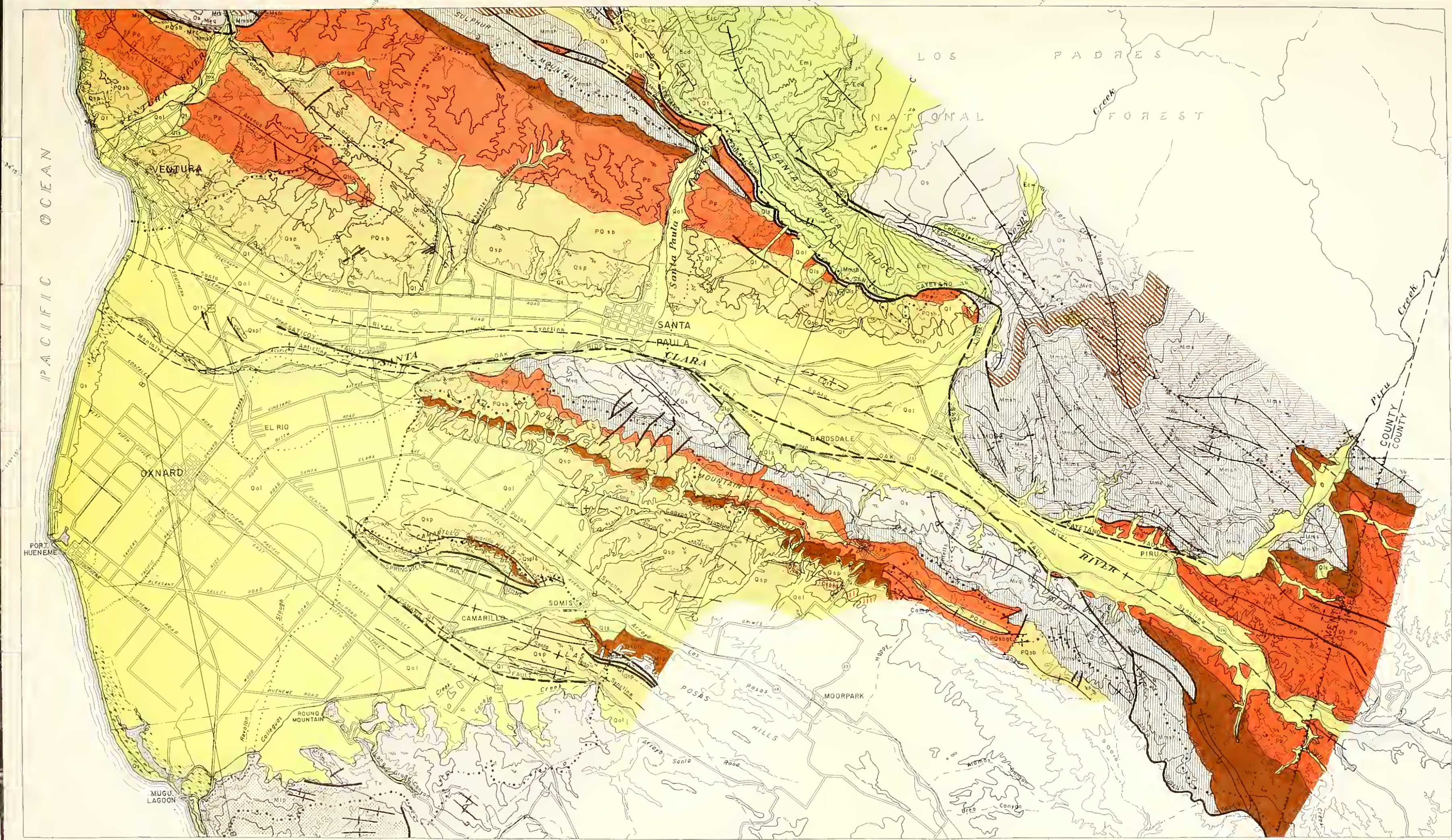
GEOLOGIC SECTION A - A

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
AREAL GEOLOGY  
1953  
Scale of miles  










SEE PLATE B-1C FOR GEOLOGIC LEGEND



GEOLOGIC SECTION B-B'



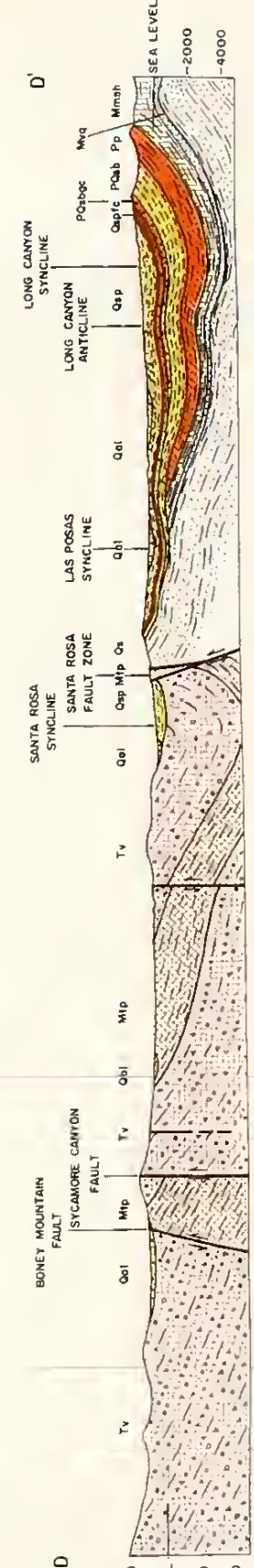
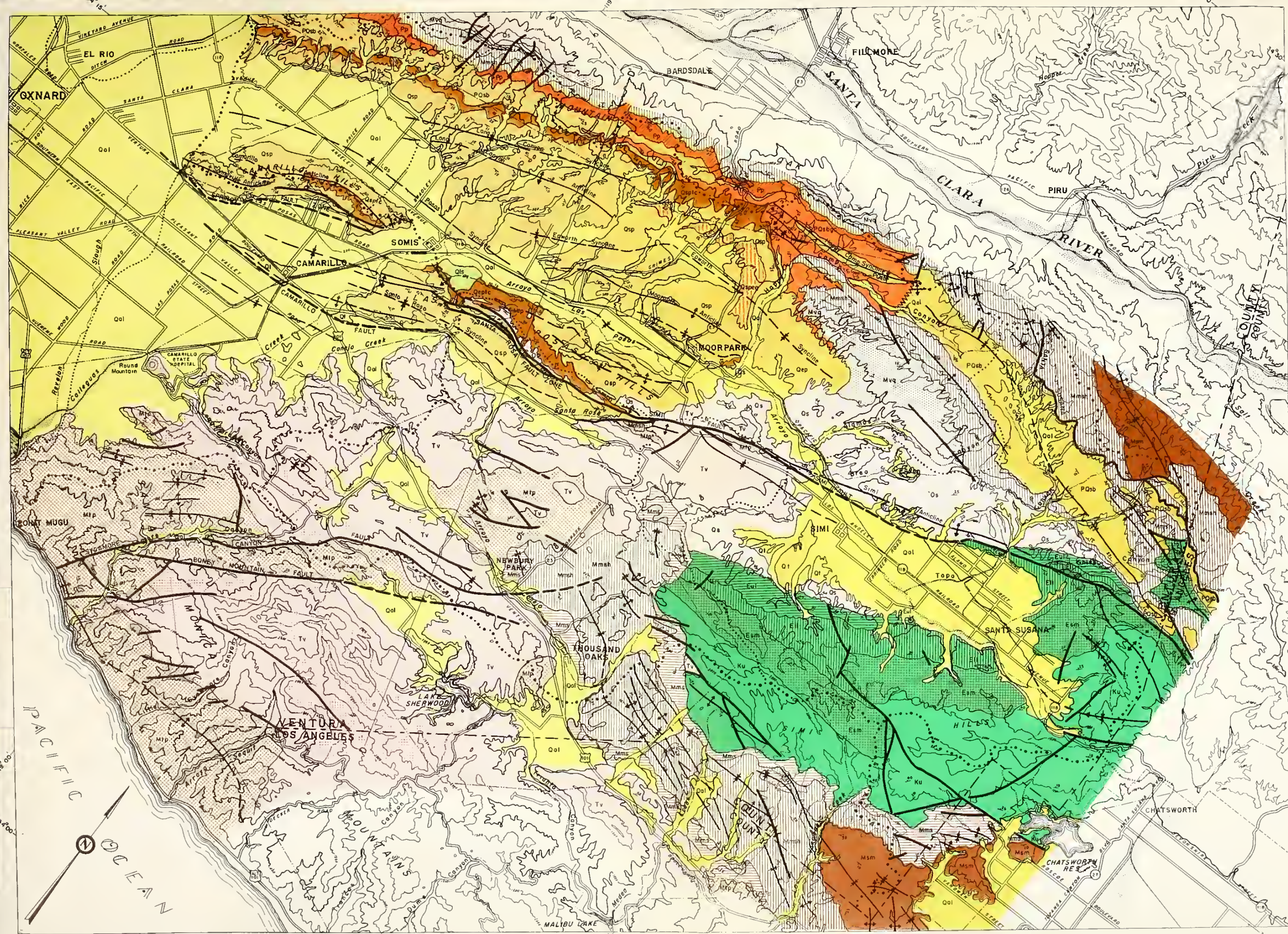
GEOLOGIC SECTION C-C'

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**AREAL GEOLOGY**  
1953  
Scale of miles  
0 1 2 3









LEGEND	
QUATERNARY	
RECENT	Qol Alluvium (Sand, Gravel and clay) Water-bearing
	Qs Dune sand
UPPER PLEISTOCENE	Qls Landslide
	Ql Terrace deposits and older alluvium. Marine and continental gravel, sand and clay. Water-bearing.
LOWER PLEISTOCENE	Qsp San Pedro formation. Marine and continental sand, gravel, silt and clay. Generally water-bearing.
	Qspb Epworth gravels. Water-bearing member of the San Pedro formation.
	Qspc Fox Canyon member of the San Pedro formation. Marine sand & gravel. Water-bearing.
PLEISTOCENE	Qspb Santa Barbara formation. Marine silt, clay, sand and gravel. Generally nonwater-bearing.
	Qspc Grimes Canyon member of the Santa Barbara formation. Marine sand & gravel. Water-bearing.
	Pica formation. Marine siltstone, sandstone, conglomerate and shale. Nonwater-bearing.
	"Santa Margarita" formation. Marine shale, sandstone and conglomerate. Generally nonwater-bearing.
MIOCENE	Mmsh Modelo shale. Marine. Locally water-bearing.
	Mms Modelo sandstone. Marine. Locally water-bearing.
	Rincon formation. Marine shale. Nonwater-bearing.
	Tapanga formation. Marine sandstone, conglomerate, shale and associated volcanics. Locally water-bearing.
	Vaquero formation. Marine sandstone and shale. Nonwater-bearing.
OLIGOCENE	Qs Sespe formation. Continental sandstone, conglomerate and shale. Locally water-bearing.
Eocene	Ecw Coldwater sandstone. Marine. Generally nonwater-bearing.
	Ecd Cozy Dell shale. Marine. Nonwater-bearing.
	Emj Matilija sandstone. Marine. Nonwater-bearing.
	Ejc Juncal formation. Marine sandstone and shale. Nonwater-bearing.
	Eul Upper Lajas formation. Marine sandstone, some shale. Locally water-bearing.
	Ell Lower Lajas formation. Marine shale. Generally nonwater-bearing.
CRETACEOUS	
Eocene	Esm Santa Susana-Martinez formation. Marine sandstone, conglomerate and shale. Locally water-bearing.
PALEOCENE	Ku Undifferentiated formations of Cretaceous Age. Marine sandstone, some conglomerate and shale. Locally water-bearing.
MIOCENE	Tv Volcanics. Basaltic flows and agglomerates with some interbedded sediments. Basaltic and andesitic intrusions. Generally water-bearing.
CONTACT	
ANTICLINE	
SYNCLINE	
FAULT	
DIP AND STRIKE	
OVERTURNED BED	
VERTICAL BED	
HORIZONTAL BED	

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**AREAL GEOLOGY**  
1953  
Scale of miles  
1 1/2 0 1 2 3







# STRATIGRAPHIC COLUMNS - VENTURA COUNTY REGION

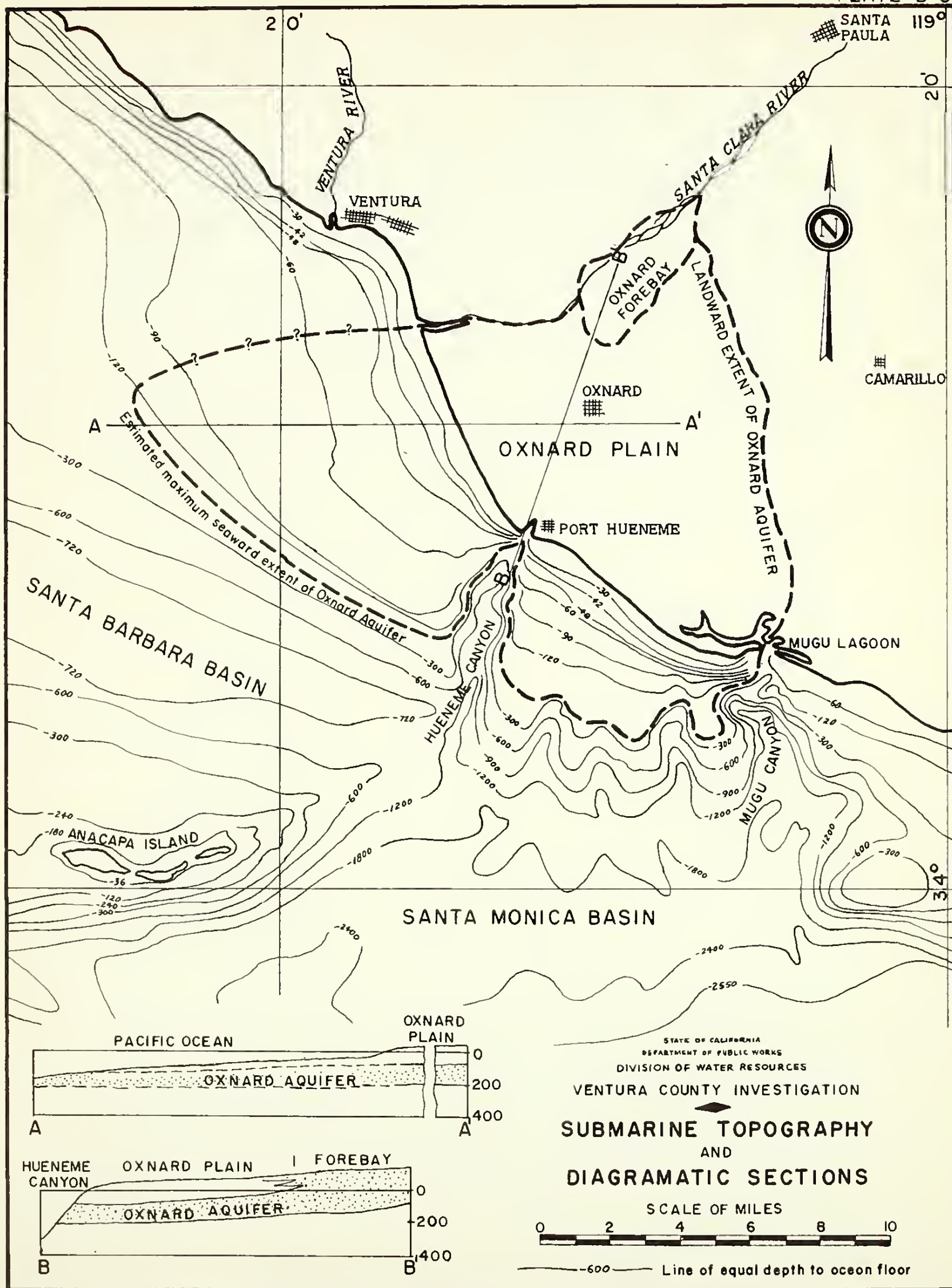
AGE		SANTA MONICA MOUNTAINS CONEJO AND TIERRA REJADA BASINS- MALIBU HYDROLOGIC UNIT	OAK RIDGE-SOUTH MOUNTAIN EAST LAS POSAS, WEST LAS POSAS AND SANTA ROSA BASINS	SIMI HILLS-SANTA SUSANA MOUNTAINS SIMI SUBUNIT	COASTAL PLAIN MOUND, OXNARD FOREBAY, OXNARD PLAIN AND PLEASANT VALLEY BASINS	VENTURA RIVER DRAINAGE AND SANTA PAULA BASIN UPPER AND LOWER VENTURA RIVER BASINS OJAI AND UPPER OJAI BASINS	SESPE-PIRU CREEK AREA FILLMORE-PIRU SUBUNITS NORTH OF THE SANTA CLARA RIVER	CUYAMA RIVER DRAINAGE AREA	EASTERN SANTA CLARA RIVER DRAINAGE AREA EASTERN BASIN	
QUATERNARY	RECENT	ALLUVIUM AND TERRACE DEPOSITS: Clay sand and gravel, 0-60' thick.	STREAM AND TERRACE DEPOSITS: Clay and silt with sand and gravel in some areas, 0-200' thick.	SIMI BASIN: Stream, terrace, alluvial fan and swamp deposits, 0-200' thick  SANTA SUSANA MOUNTAINS: Clays, sands and gravels, 0-50' thick	OXNARD PLAIN: Stream deposits sand and gravel 20' ELSEWHERE: Clay, silt and sand, 0-50' thick.	Stream deposited clay, sand and gravel, 0-700' thick.	Stream deposited sand and gravel with some clay 0-250' thick.	Stream and terrace deposits: sand, gravel and some clay, 0-100' thick.	Stream and terrace deposits: Sand and gravel, 0-150' thick.	
	PLEISTOCENE	UPPER	Unconformity	Unconformity	Unconformity	Unconformity	Unconformity	Unconformity	Unconformity	
		LOWER	Missing	Missing	Missing	Missing	Missing	Missing	Missing or not recognized.	
	PLIOCENE	Missing	Missing	Missing	Missing	Missing	Missing	Missing	Missing or not recognized.	
TERTIARY	MIOCENE	UPPER	"SANTA MARGARITA" FORMATION: Diatomaceous shale and sandstone, 1300' thick. Unconformity	Missing	"SANTA MARGARITA" FORMATION: Siliceous shale, 2000' thick.	"SANTA MARGARITA" FORMATION: Siliceous shale and sandstone, 1800' thick.	"SANTA MARGARITA" FORMATION: Shale and sand- stone, 1000' thick.	Unconformity	Missing	SANTA MARGARITA FORMATION: Siliceous shale
		MIDDLE	Modela shale and sandstone, 1000' thick. Unconformity	Modela shale, 1500' thick Unconformity	Modela shale and sandstone volcanic intrusion at base. Unconformity	"SANTA MARGARITA" AND MODELO FORMATIONS: Shale and sandstone. Unconformity	MODELO SHALE: Brown to white, siliceous shale 1500' thick.			
	LOWER	TOPANGA FORMATION: marine sandstone, conglomerate and brown to black shale 6000-9000' thick.	Missing	Missing or included in modela shale.	TOPANGA FORMATION AND VOLCANICS: 11000' thick.	MODELO SHALE: 200'-1600' thick. Sandstone, 200'-2000' thick. Shale, 500' thick.	QUATATL FORMATION: Continental red gypsiferous clay, sandstone and conglomerate, 4500' thick.	Missing	Missing	
	OLIGOCENE	Missing	Missing	Missing	Missing	Missing	Missing	Missing	Missing	
Eocene	UPPER	Missing	Missing	Missing	Missing	Missing	Missing	Missing		
	LOWER	Missing	Missing	Missing	Missing	Missing	Missing	Missing		
PALEOCENE	Missing	Missing	Missing	Missing	Missing	Missing	Missing	Missing		
CRETACEOUS	Missing	Missing	Missing	Missing	Missing	Missing	Missing	Missing		
PRE-CRETACEOUS	Missing	Missing	Missing	Missing	Missing	Missing	Missing	Missing		

NOTE: Since stratigraphic units do not generally conform with the delineated basin or watershed boundary, the column headings refer only to generalized areas not indicated on any plates. The various subunits or basins are listed beneath the column headings to indicate the stratigraphic relationships therein.

NOTE: Since stratigraphic units do not generally conform with the delineated basin or watershed boundary, the column headings refer only to generalized areas not indicated on any plates. The various subunits or basins are listed beneath the column headings to indicate the stratigraphic relationships therein.











## APPENDIX C

### ESTIMATES OF COST

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## ESTIMATES OF COST

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ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 92,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 523 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 92,000 acre-feet
Elevation of crest of spillway: 503 feet	Capacity of spillway with 10.6-foot freeboard: 17,000 second-feet
Height of dam to spillway crest, above stream bed: 178 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Diversion of stream and de- watering of foundation		lump sum	\$ 10,000
Excavation, stripping			
Stream bed, common	780,300 cu.yd.	\$ 0.41	319,900
rock	41,000 cu.yd.	1.10	45,100
Abutments, random	296,300 cu.yd.	0.88	260,700
Right abutment, slide area	50,000 cu.yd.	0.82	41,000
Excavation, from borrow pits	4,319,400 cu.yd.	0.44	1,900,500
Embankment, compacted	4,715,400 cu.yd.	0.24	1,131,700
Gravel fill, pervious drain	54,400 cu.yd.	4.60	250,200
Rock riprap	55,300 cu.yd.	4.00	221,200
Drilling grout holes	8,750 lin.ft.	3.00	26,300
Pressure grouting	4,400 cu.ft.	4.00	17,600
Slope stabilization, planting	17.2 acres	1,000.00	17,200
			<u>\$4,241,400</u>
<b>Spillway</b>			
Excavation			
Channel	82,600 cu.yd.	2.75	227,200
Cutoff	690 cu.yd.	6.00	4,100
Concrete			
Weir and bucket	625 cu.yd.	35.00	21,900
Walls	520 cu.yd.	40.00	20,800
Floor	1,400 cu.yd.	30.00	42,000
Cutoff	690 cu.yd.	35.00	24,200
Reinforcing steel	323,300 lbs.	0.15	48,500
			<u>388,700</u>
<b>Outlet Works</b>			
Excavation			
Stripping for tower	2,000 cu.yd.	1.50	3,000
Rock, tower foundation	160 cu.yd.	6.00	1,000
Rock, conduit trench	1,200 cu.yd.	6.00	7,200
Concrete			
Tower	465 cu.yd.	80.00	37,200
Pipe encasement	640 cu.yd.	40.00	25,600
Reinforcing steel	110,000 lbs.	0.15	16,500
Pipe, reinf. conc. 42- inch dia.	1,000 lin.ft.	21.00	21,000



ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 92,000 ACRE-FEET  
(continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Outlet Works (continued)</b>			
Gate valves, 30-in. dia.	3 each	\$3,000.00	\$ 9,000
Gate valves, 24-in. dia.	6 each	2,000.00	12,000
Floor stands and stems		lump sum	6,000
Reducing thimbles, cast iron		lump sum	2,500
Miscellaneous metal work	15,000 lbs.	0.40	6,000
Control house		lump sum	<u>2,500</u>
			\$149,500
<b>Reservoir</b>			
Land and improvements		lump sum	1,500,000
Highway relocation		lump sum	415,000
Relocation of utilities		lump sum	60,500
Clearing reservoir land	800 acres	150.00	<u>120,000</u>
			2,095,500
Subtotal			\$6,875,100
Administration and engineering, 10%			\$ 687,500
Contingencies, 15%			<u>1,031,300</u>
Interest during construction			343,800
TOTAL			\$8,937,700
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 357,500
Amortization, 40-year sinking fund at 4%			94,000
Operation and maintenance			<u>15,000</u>
TOTAL			\$ 466,500

ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 105,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 533 feet U.S.G.S. Datum	Capacity of reservoir to crest of spillway: 105,000 acre-feet
Elevation of crest of spillway: 513 feet	Capacity of spillway with 9-foot freeboard: 17,000 second-feet
Height of dam to spillway crest, above stream bed: 188 feet	

Item	:	Quantity	:	Unit	:	price	:	Cost
------	---	----------	---	------	---	-------	---	------

CAPITAL COSTS

Dam

Diversion of stream and dewatering of foundation				lump sum \$	10,000	
Excavation, stripping						
Stream bed, common	830,400	cu.yd.	\$	0.41	340,500	
rock	43,800	cu.yd.		1.10	48,200	
Abutments, random	310,400	cu.yd.		0.88	273,200	
Right abutment, slide area	50,000	cu.yd.		0.82	41,000	
Excavation, from borrow pits	5,013,800	cu.yd.		0.44	2,206,100	
Embankment, compacted	5,461,800	cu.yd.		0.24	1,310,800	
Gravel fill, pervious drain	62,700	cu.yd.		4.60	288,400	
Rock riprap	68,000	cu.yd.		4.00	272,000	
Drilling grout holes	10,330	lin.ft.		3.00	31,000	
Pressure grouting	5,170	cu.ft.		4.00	20,700	
Slope stabilization, planting	17.3	acres	1,000.00		<u>17,300</u>	\$4,859,200

Spillway

Excavation						
Channel	55,300	cu.yd.		2.75	152,100	
Cutoff	640	cu.yd.		6.00	3,800	
Concrete						
Weir and bucket	590	cu.yd.		35.00	20,700	
Walls	630	cu.yd.		40.00	25,200	
Floor	1,530	cu.yd.		30.00	45,900	
Cutoff	540	cu.yd.		35.00	18,900	
Reinforcing steel	330,000	lbs.		0.15	<u>49,500</u>	316,100

Outlet Works

Excavation						
Stripping for tower	2,000	cu.yd.		1.50	3,000	
Rock, tower foundation	390	cu.yd.		6.00	2,300	
Rock, conduit trench	1,320	cu.yd.		6.00	7,900	
Concrete						
Tower	520	cu.yd.		80.00	41,600	
Pipe encasement	700	cu.yd.		40.00	28,000	
Reinforcing steel	121,900	lbs.		0.15	18,300	

ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 105,000 ACRE-FeET  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Outlet Works (Continued)				
Pipe, reinf. conc. 42-in. dia.	1,100	lin.ft.	\$ 21.00	\$ 23,100
Gate valves, 30-in. dia.	4	each	3,000.00	12,000
Gate valves, 24-in. dia.	5	each	2,000.00	10,000
Floor stands and stems			lump sum	6,500
Reducing thimbles, cast iron			lump sum	3,000
Miscellaneous metal work	20,000	lbs.	0.40	8,000
Control house			lump sum	<u>2,500</u>
				\$ 166,200
Reservoir				
Land and improvements			lump sum	1,500,000
Highway relocation			lump sum	415,000
Relocation of utilities			lump sum	60,500
Clearing reservoir land	850	acres	150.00	<u>127,500</u>
				2,103,000
Subtotal				\$7,444,500
Administration and engineering, 10%				\$ 744,450
Contingencies, 15%				1,116,750
Interest during construction				<u>372,225</u>
TOTAL				\$9,677,800
ANNUAL COSTS				
Interest, 4%				\$ 387,100
Amortization, 40-year sinking fund at 4%				101,800
Operation and maintenance				<u>18,000</u>
TOTAL				\$ 506,900



ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 130,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 547 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 130,000 acre-feet
Elevation of crest of spillway: 527 feet	Capacity of spillway with 9-foot freeboard: 17,000 second feet
Height of dam to spillway crest, above stream bed: 202 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Diversion of stream and dewatering of foundation		lump sum	\$	10,000
Excavation, stripping				
Stream bed, common	986,800	cu.yd.	\$ 0.41	404,600
rock	55,800	cu.yd.	1.10	61,400
Abutments, random	476,300	cu.yd.	0.88	419,100
Right abutment, slide area	50,000	cu.yd.	0.82	41,000
Excavation, from borrow pits	6,390,600	cu.yd.	0.44	2,811,900
Embankment, compacted	6,934,100	cu.yd.	0.24	1,664,200
Gravel fill, pervious drain	70,640	cu.yd.	4.60	324,900
Rock riprap	120,400	cu.yd.	4.00	481,600
Drilling grout holes	15,500	lin.ft.	3.00	46,500
Pressure grouting	7,740	cu.ft.	4.00	31,000
Slope stabilization, planting	19.7	acres	1,000.00	19,700
				<u>\$6,315,900</u>
<b>Spillway</b>				
Excavation				
Channel	44,950	cu.yd.	2.75	123,600
Cutoff	610	cu.yd.	6.00	3,700
Concrete				
Weir and bucket	590	cu.yd.	35.00	20,700
Walls	610	cu.yd.	40.00	24,400
Floor	1,170	cu.yd.	30.00	35,100
Cutoff	510	cu.yd.	35.00	17,900
Reinforcing steel	287,800	lbs.	0.15	43,200
				<u>268,600</u>
<b>Outlet Works</b>				
Excavation				
Stripping for tower	2,000	cu.yd.	1.50	3,000
Rock, tower foundation	390	cu.yd.	6.00	2,300
Rock, conduit trench	2,090	cu.yd.	6.00	12,500
Concrete				
Tower	570	cu.yd.	80.00	45,600
Pipe encasement	740	cu.yd.	40.00	29,600
Reinforcing steel	129,000	lbs.	0.15	19,400
Pipe, reinf. conc. 48- in. dia.	1,150	lin.ft.	24.00	27,600

ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 130,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Outlet Works (Continued)			
Gate valves, 30-in. dia.	5 each	\$3,000.00	\$ 15,000
Gate valves, 24-in. dia.	4 each	2,000.00	8,000
Floor stands and stems		lump sum	6,500
Reducing thimbles, cast iron		lump sum	3,000
Miscellaneous metal work	20,000 lbs.	0.40	8,000
Control house		lump sum	<u>2,500</u>
			\$ 183,000
Reservoir			
Land and improvements		lump sum	1,500,000
Highway relocation		lump sum	415,000
Relocation of utilities		lump sum	60,500
Clearing reservoir land	900 acres	150.00	<u>135,000</u>
			<u>2,110,500</u>
Subtotal			\$ 8,878,000
Administration and engineering, 10%			\$ 887,800
Contingencies, 15%			<u>1,331,700</u>
Interest during construction			<u>665,900</u>
TOTAL			\$11,763,400
ANNUAL COSTS			
Interest, 4%			\$ 470,500
Amortization, 40-year sinking fund at 4%			123,800
Operation and maintenance			<u>21,000</u>
TOTAL			\$ 615,300

ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 156,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 560 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 156,000 acre- feet.
Elevation of crest of spillway: 540.5 feet	
Height of dam to spillway crest, above stream bed: 215 feet	Capacity of spillway with 8.5- foot freeboard: 17,000 second-feet

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Diversion of stream and dewatering of foundation		lump sum	\$	10,000
Excavation, stripping				
Stream bed, common	1,132,700	cu.yd.	\$ 0.41	464,400
rock	59,600	cu.yd.	1.10	65,600
Abutments, random	1,404,400	cu.yd.	0.88	1,235,900
Right abutment, slide area	50,000	cu.yd.	0.82	41,000
Excavation, from borrow pits	11,731,900	cu.yd.	0.44	5,162,000
Embankment, compacted	12,441,800	cu.yd.	0.24	2,986,000
Gravel fill, pervious drain	77,600	cu.yd.	4.60	357,000
Rock riprap	270,800	cu.yd.	4.00	1,083,200
Drilling grout holes	19,850	lin.ft.	3.00	59,600
Pressure grouting	9,950	cu.ft.	4.00	39,800
Slope stabilization, planting	31.9 acres		1,000.00	<u>31,900</u>
				\$11,536,400
<b>Spillway</b>				
Excavation				
Channel	158,400	cu.yd.	2.75	435,600
Cutoff	720	cu.yd.	6.00	4,300
Concrete				
Weir and bucket	395	cu.yd.	35.00	13,800
Walls	840	cu.yd.	40.00	33,600
Floor	2,070	cu.yd.	30.00	62,100
Cutoff	720	cu.yd.	35.00	25,200
Reinforcing steel	403,000	lbs.	0.15	<u>60,500</u>
				635,100
<b>Outlet Works</b>				
Excavation				
Stripping for tower	1,370	cu.yd.	1.50	2,100
Rock, tower foundation	550	cu.yd.	6.00	3,300
Rock, conduit trench	3,160	cu.yd.	6.00	19,000



ESTIMATED COST OF CASITAS DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 156,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Outlet Works (Continued)				
Concrete				
Tower	693 cu.yd.	\$	80.00	\$ 55,400
Pipe encasement	1,110 cu.yd.		40.00	44,400
Reinforcing steel	182,500 lbs.		0.15	27,400
Pipe, reinf. con. 48-in. dia.	1,740 lin.ft.		24.00	41,800
Gate valves, 30-in. dia.	6 each		3,000.00	18,000
Gate valves, 36-in. dia.	3 each		5,000.00	15,000
Floor stands and stems			lump sum	6,500
Reducing thimbles, cast iron			lump sum	3,000
Miscellaneous metal work	25,000 lbs.		0.40	10,000
Control house			lump sum	<u>2,500</u>
				\$ 248,400
Reservoir				
Land and improvements			lump sum	1,500,000
Highway relocation			lump sum	415,000
Relocation of utilities			lump sum	60,500
Clearing reservoir land	1,000 acres		150.00	<u>150,000</u>
				2,125,500
Subtotal				\$14,545,400
Administration and engineering, 10%				\$ 1,454,500
Contingencies, 15%				2,181,800
Interest during construction				<u>1,454,500</u>
TOTAL				\$19,636,200
ANNUAL COSTS				
Interest, 4%				\$ 785,500
Amortization, 40-year sinking fund at 4%				206,600
Operation and maintenance				<u>25,000</u>
TOTAL				\$ 1,017,100

ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR WITH  
CONDUIT OF 100 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE  
(Based on prices prevailing in spring of 1953)

Elevation at crest of weir:	Total length of pipe line: 17,600 feet
910 feet, U.S.G.S. datum	Total length of canal and flume:
Height of weir above stream bed:	14,730 feet
10 feet	

Item	Quantity	Unit	Price	Cost
<b>CAPITAL COSTS</b>				
<b>Diversion Works</b>				
Excavation	200 cu.yd.	\$	4.00	\$ 800
Stripping	870 cu.yd.		3.00	2,600
Concrete				
Weir and cutoff	750 cu.yd.		35.00	26,300
Walls	20 cu.yd.		50.00	1,000
Reinforcing steel	2,500 lbs.		0.15	400
Trash rack steel	1,000 lbs.		0.20	200
Outlet gates			lump sum	2,200
				<u>\$33,500</u>
<b>Pipe Line</b>				
Pipe, reinforced concrete, 42-inch, installed including earthwork	17,600 lin.ft.		23.31	410,300
Air valves, blowoffs, and structures			lump sum	26,000
Sand trap			lump sum	9,800
				<u>446,100</u>
<b>Canal and Flume</b>				
Excavation	52,690 cu.yd.		0.45	23,700
Compacted fill	6,870 cu.yd.		0.31	2,100
Shotcrete lining	21,600 sq.yd.		3.50	75,600
Flume, semicircular, metal, 6.4 foot diameter, including structures	600 lin.ft.		21.80	13,100
Flume, semicircular, metal, 7.0 foot diameter including structures	30 lin.ft.		18.20	500
Special structure			lump sum	17,000
Farm road bridges	4 each		2,200.00	8,800
				<u>140,800</u>
<b>Rights of Way</b>				
Canal	20 acres		1,000.00	20,000
Pipe line	21 acres		150.00	3,200
				<u>23,200</u>
Subtotal				<u>\$643,600</u>

ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR WITH  
CONDUIT OF 100 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Administration and engineering, 10%			\$ 64,400
Contingencies, 15%			96,500
Interest during construction			<u>32,200</u>
TOTAL			\$836,700
ANNUAL COSTS			
Interest, 4%			\$ 33,500
Amortization, 40-year sinking fund at 4%			8,800
Operation and maintenance			<u>4,000</u>
TOTAL			\$ 46,300



ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR  
WITH CONDUIT OF 150 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE  
(Based on prices prevailing in spring of 1953)

Elevation at crest of weir:	Total length of pipe line: 17,600 feet
910 feet, U.S.G.S. datum	Total length of canal and flume:
Height of weir above stream bed:	14,730 feet
10 feet	

Item	Quantity	Unit	price	Cost
<b>APITAL COSTS</b>				
<b>Diversion Works</b>				
Excavation	200 cu.yd.	\$	4.00	\$ 800
Stripping	870 cu.yd.		3.00	2,600
Concrete				
Weir and cutoff	750 cu.yd.		35.00	26,300
Walls	20 cu.yd.		50.00	1,000
Reinforcing steel	2,500 lbs.		0.15	400
Trash rack steel	1,000 lbs.		0.20	200
Outlet gates		lump sum		<u>2,200</u> \$33,500
<b>Pipe Line</b>				
Pipe, reinforced concrete, 48-inch diameter, installed	17,600 lin.ft.		26.62	468,500
Air valves, blowoffs, and structures		lump sum		28,100
Sand trap		lump sum		<u>9,800</u> 506,400
<b>Canal and Flume</b>				
Excavation	71,560 cu.yd.		0.45	32,200
Compacted fill	11,610 cu.yd.		0.31	3,600
Shotcrete lining	29,328 sq.yd.		3.50	102,600
Flume, semicircular, metal, 7.6 foot diameter, including structures	600 lin.ft.		29.40	17,600
Flume, semicircular, metal, 8.3 foot diameter, including structures	30 lin.ft.		25.80	800
Special structures		lump sum		17,000
Farm road bridges	4 each		2,200.00	<u>8,800</u> 182,600
<b>Rights of Way</b>				
Canal	34 acres		1,000.00	34,000
Pipe line	21 acres		150.00	<u>3,200</u> 37,200
Subtotal				\$759,700

ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR  
WITH CONDUIT OF 150 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE  
(Continued)

Item	:	Quantity	:	Unit price	:	Cost
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CAPITAL COSTS

Administration and engineering, 10%				\$	76,000
Contingencies, 15%					113,900
Interest during construction					<u>38,000</u>
TOTAL				\$	987,600

ANNUAL COSTS

Interest, 4%				\$	39,500
Amortization, 40-year sinking fund at 4%					10,400
Operation and maintenance					<u>4,000</u>
TOTAL				\$	53,900

ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR  
WITH CONDUIT OF 200 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE

(Based on prices prevailing in spring of 1953)

Elevation of crest of weir: 910 feet, U.S.G.S. datum	Total length of pipe line: 17,600 feet
Height of weir above stream bed: 10 feet	Total length of canal and flume: 14,730 feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Diversion Works</b>			
Excavation	200 cu.yd.	\$ 4.00	\$ 800
Stripping	870 cu.yd.	3.00	2,600
Concrete			
Weir and cutoff	750 cu.yd.	35.00	26,300
Walls	20 cu.yd.	50.00	1,000
Reinforcing steel	2,500 lbs.	0.15	400
Trash rack steel	1,000 lbs.	0.20	200
Outlet gates		lump sum	<u>2,200</u> \$ 33,500
<b>Pipe Line</b>			
Pipe, reinforced concrete			
54-inch dia., installed	17,600 lin.ft.	30.97	545,100
Air valves, blowoffs, and structures		lump sum	30,000
Sand trap		lump sum	<u>12,300</u> 587,400
<b>Canal and Flume</b>			
Excavation	76,700 cu.yd.	0.45	34,500
Compacted fill	11,610 cu.yd.	0.31	3,600
Shotcrete lining	31,580 sq.yd.	3.50	110,500
Flume, semicircular, metal, 8.3-foot dia., including structures	600 lin.ft.	34.60	20,800
Flume, semicircular, metal, 8.9-foot dia., including structures	30 lin.ft.	26.60	800
Special structures		lump sum	18,100
Farm road bridges	4 each	2,200.00	<u>8,800</u> 197,100
<b>Right of Way</b>			
Canal	34 acres	1,000.00	34,000
Pipe line	21 acres	150.00	<u>3,200</u> 37,200
Subtotal			\$ 855,200



ESTIMATED COST OF VENTURA RIVER DIVERSION TO CASITAS RESERVOIR  
WITH CONDUIT OF 200 SECOND-FOOT CAPACITY  
AND DIVERSION AT THE MIDDLE SITE  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Administration and engineering, 10%			\$ 85,500
Contingencies, 15%			128,300
Interest during construction			<u>42,800</u>
TOTAL			\$1,111,800
ANNUAL COSTS			
Interest, 4%			\$ 44,500
Amortization, 40-year sinking fund at 4%			11,700
Operation and maintenance			<u>4,000</u>
TOTAL			\$ 60,200

ESTIMATED COST OF FERNDAL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 12,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,100 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 12,000 acre-feet
Elevation of crest of spillway: 1,075 feet	Capacity of spillway with 5-foot freeboard: 37,000 second-feet
Height of dam to spillway crest, above stream bed: 165 feet	

Item	Quality	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	30,000
Diversion of stream and dewatering of foundation		lump sum		10,000
Stripping topsoil	26,600 cu.yd.	\$	0.60	16,000
Foundation excavation				
Abutment	208,500 cu.yd.		1.10	229,400
Channel	20,700 cu.yd.		0.60	12,400
Embankment				
Impervious	902,900 cu.yd.		0.70	632,000
Pervious	1,408,500 cu.yd.		0.45	633,800
Rock riprap	38,000 cu.yd.		4.00	152,000
Drilling grout holes	5,880 lin.ft.		3.00	17,600
Pressure grouting	3,920 cu.ft.		4.00	<u>15,700</u>
				\$1,748,900
<b>Spillway</b>				
Excavation	328,800 cu.yd.		2.00	657,600
Concrete				
Weir and cutoff	1,440 cu.yd.		35.00	50,400
Floor	1,340 cu.yd.		30.00	40,200
Walls	840 cu.yd.		40.00	33,600
Reinforcing steel	267,800 lbs.		0.15	<u>40,200</u>
				822,000
<b>Outlet Works</b>				
Excavation				
Inlet structure	300 cu.yd.		5.00	1,500
Conduit trench	7,920 cu.yd.		6.00	47,500
Concrete				
Inlet structure	220 cu.yd.		60.00	13,200
Conduit encasement	3,590 cu.yd.		40.00	143,600
Reinforcing steel	183,900 lbs.		0.15	27,600
Miscellaneous metal work	32,400 lbs.		0.40	13,000
Steel pipe 42-inch dia.	198,000 lbs.		0.28	55,500
High pressure slide gate		lump sum		25,000
Needle valve, 36-inch dia.		lump sum		12,000
Control house, etc.		lump sum		<u>9,100</u>
				348,000

ESTIMATED COST OF FERNDAL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 12,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Reservoir			
Land acquisition		lump sum \$	258,800
Improvements		lump sum	576,700
State road relocation		lump sum	420,000
Clearing	270 acres	\$ 150.00	<u>40,500</u> \$1,296,000
Subtotal			\$4,214,900
Administration and engineering, 10%			\$ 421,500
Contingencies, 15%			<u>632,200</u>
Interest during construction			<u>105,400</u>
TOTAL			\$5,374,000
ANNUAL COSTS			
Interest, 4%			\$ 215,000
Amortization, 40-year sinking fund at 4%			56,500
Operation and maintenance			<u>5,000</u>
TOTAL			\$ 276,500



ESTIMATED COST OF FERNDALE DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 24,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,150 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 24,000 acre-feet
Elevation of crest of spillway: 1,120 feet	Capacity of spillway with 5-foot freeboard: 37,000 second-feet
Height of dam to spillway crest, above stream bed: 210 feet	

Item	Quantity	Unit price	Cost	
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum \$	40,000	
Diversion tunnel				
15-foot diameter	1,250 lin.ft.	\$386.00	482,500	
Portal excavation	20,200 cu.yd.	0.80	16,200	
Concrete plug	260 cu.yd.	30.00	7,800	
Diversion of stream and dewatering of foundation		lump sum	10,000	
Stripping topsoil	37,000 cu.yd.	0.60	22,200	
Foundation excavation				
Abutment	349,100 cu.yd.	1.10	384,000	
Channel	25,200 cu.yd.	0.60	15,100	
Embankment				
Impervious	1,757,400 cu.yd.	0.70	1,230,200	
Pervious	2,343,900 cu.yd.	0.45	1,054,800	
Rock riprap	56,830 cu.yd.	4.00	227,300	
Drilling grout holes	7,440 lin.ft.	3.00	22,300	
Pressure grouting	4,960 cu.ft.	4.00	19,800	\$3,532,200
<b>Spillway</b>				
Excavation	160,800 cu.yd.	2.00	321,600	
Concrete				
Weir and cutoff	970 cu.yd.	35.00	34,000	
Floor	1,270 cu.yd.	30.00	38,100	
Walls	590 cu.yd.	40.00	23,600	
Reinforcing steel	220,600 lbs.	0.15	33,100	450,400
<b>Outlet Works</b>				
Inlet structure concrete	300 cu.yd.	60.00	18,000	
Inlet structure excavation	400 cu.yd.	6.00	2,400	
Steel pipe 60-inch dia.	326,500 lbs.	0.28	91,400	
Reinforcing steel	41,000 lbs.	0.15	6,200	
High pressure slide gate		lump sum	25,000	
Needle valve 48-inch dia.		lump sum	18,000	
Miscellaneous metal work	35,000 lbs.	0.40	14,000	
Control house, etc.		lump sum	11,000	186,000

ESTIMATED COST OF FERNDALE DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 24,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Reservoir			
Land acquisition		lump sum	294,200
Improvements		lump sum	641,900
State road relocation		lump sum	420,000
Clearing	340 acres	\$ 150.00	<u>51,000</u>
			\$1,407,100
Subtotal			\$5,575,700
Administration and engineering, 10%			\$ 557,600
Contingencies, 15%			836,400
Interest during construction			<u>278,800</u>
TOTAL			\$7,248,500
ANNUAL COSTS			
Interest, 4%			\$ 289,900
Amortization, 40-year sinking fund at 4%			76,300
Operation and maintenance			<u>6,500</u>
TOTAL			\$ 372,700

ESTIMATED COST OF FERNDALE DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 34,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam:	Capacity of reservoir to crest of
1,180 feet, U.S.G.S. datum	spillway: 34,000 acre-feet
Elevation of crest of spillway:	Capacity of spillway with 5-foot
1,150 feet	freeboard: 37,000 second-feet
Height of dam to spillway crest,	
above stream bed: 240 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum \$	40,000
Diversion tunnel			
15-foot diameter	1,600 lin.ft.	\$ 386.00	617,600
Portal excavation	12,760 cu.yd.	0.80	10,200
Concrete plug	260 cu.yd.	30.00	7,800
Diversion of stream and dewatering of foundation		lump sum	10,000
Stripping topsoil	68,300 cu.yd.	0.60	41,000
Foundation excavation			
Abutment	423,000 cu.yd.	1.10	465,300
Channel	29,600 cu.yd.	0.60	17,800
Embankment			
Impervious	2,303,000 cu.yd.	0.70	1,612,100
Pervious	4,031,800 cu.yd.	0.45	1,814,300
Rock riprap	82,220 cu.yd.	4.00	328,900
Drilling grout holes	7,920 lin.ft.	3.00	23,800
Pressure grouting	5,280 cu.ft.	4.00	21,100
			<u>\$5,009,900</u>
<b>Spillway</b>			
Excavation	363,820 cu.yd.	2.00	727,600
Concrete			
Weir and cutoff	1,260 cu.yd.	35.00	44,100
Floor	2,110 cu.yd.	30.00	63,300
Walls	1,630 cu.yd.	40.00	65,200
Reinforcing steel	340,500 lbs.	0.15	51,100
			<u>951,300</u>
<b>Outlet Works</b>			
Inlet structure concrete	300 cu.yd.	60.00	18,000
Inlet structure excavation	400 cu.yd.	6.00	2,400
Steel pipe 60-inch dia.	381,600 lbs.	0.28	106,800
Reinforcing steel	41,000 lbs.	0.15	6,200
High pressure slide gate		lump sum	25,000
Needle valve 48-inch dia.		lump sum	18,000
Miscellaneous metal work	40,000 lbs.	0.40	16,000
Control house, etc.		lump sum	11,000
			<u>203,400</u>



ESTIMATED COST OF FERNDALE DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 34,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Reservoir			
Land acquisition		lump sum \$	294,200
Improvements		lump sum	641,900
State road relocation		lump sum	420,000
Clearing	450 acres	\$ 150.00	<u>67,500</u> <u>\$1,423,600</u>
Subtotal			\$7,588,200
Administration and engineering, 10%			\$ 758,800
Contingencies, 15%			<u>1,138,200</u>
Interest during construction			<u>379,400</u>
TOTAL			\$9,864,600
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 394,600
Amortization, 40-year sinking fund at 4%			103,800
Operation and maintenance			<u>7,000</u>
TOTAL			\$ 505,400

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 35,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam:	Capacity of reservoir to crest of spillway:
3,400 feet, Santa Clara Water Conservation District datum, 1932	35,000 acre-feet
Elevation of crest of spillway:	Capacity of spillway with 5-foot freeboard:
3,378 feet	50,000 second-feet
Height of dam to spillway crest, above stream bed: 178 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum \$	40,000
Diversion of stream and dewatering of foundation		lump sum	10,000
Stripping topsoil	33,150 cu.yd.	\$ 0.50	16,600
Foundation excavation			
Abutment	63,630 cu.yd.	1.60	101,800
Channel	45,840 cu.yd.	0.60	27,500
Embankment			
Impervious	655,560 cu.yd.	0.74	485,100
Random	1,264,070 cu.yd.	0.58	733,200
Rock riprap	35,200 cu.yd.	4.00	140,800
Gravel fill, pervious drain	19,100 cu.yd.	5.25	100,300
Drilling grout holes	4,380 lin.ft.	3.00	13,100
Pressure grouting	2,920 cu.ft.	4.00	11,700
Slope stabilization, planting	7.5 acres	1,000.00	<u>7,500</u>
			\$1,687,600
<b>Spillway</b>			
Excavation, unclassified	343,900 cu.yd.	2.00	687,800
Concrete			
Weir and cutoff	920 cu.yd.	35.00	32,200
Floor	1,930 cu.yd.	30.00	57,900
Walls	690 cu.yd.	40.00	27,600
Reinforcing steel	341,700 lbs.	0.15	<u>51,300</u>
			856,800
<b>Outlet Works</b>			
Excavation			
Inlet structure	300 cu.yd.	5.00	1,500
Conduit trench	8,890 cu.yd.	6.00	53,300
Concrete			
Inlet structure	220 cu.yd.	60.00	13,200
Conduit encasement	2,960 cu.yd.	40.00	118,400
Reinforcing steel	152,400 lbs.	0.15	22,900
Miscellaneous metal work	32,000 lbs.	0.40	12,800

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 35,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Outlet Works (Continued)				
Steel pipe 54-inch dia.	221,000	lbs.	\$ 0.28	\$ 61,900
High pressure slide gate			lump sum	25,000
48" Howell-Bunger valve			lump sum	12,000
Control house, etc.			lump sum	<u>9,000</u>
				\$ 330,000
Reservoir				
Land acquisition			lump sum	25,000
Clearing	760 acres		50.00	38,000
Access road			lump sum	<u>40,000</u>
				103,000
Subtotal				\$2,977,400
Administration and engineering, 10%				\$ 297,700
Contingencies, 15%				446,600
Interest during construction				<u>74,400</u>
TOTAL				\$3,796,100
ANNUAL COSTS				
Interest, 4%				\$ 151,800
Amortization, 40-year sinking fund at 4%				39,900
Operation and maintenance				<u>7,500</u>
TOTAL				\$ 199,200



ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 43,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam:	Capacity of reservoir to crest of
3,410 feet, Santa Clara Water	spillway: 43,000 acre-feet
Conservation District datum, 1932	Capacity of spillway with 5-foot
Elevation of crest of spillway:	freeboard: 50,000 second-feet
3,390 feet	
Height of dam to spillway crest,	
above stream bed: 190 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	40,000
Diversion of stream and				
dewatering of foundation		lump sum		10,000
Stripping topsoil	35,000 cu.yd.	\$	0.50	17,500
Foundation excavation				
Abutment	85,800 cu.yd.		1.60	137,300
Channel	67,600 cu.yd.		0.60	40,600
Embankment				
Impervious	852,000 cu.yd.		0.74	630,500
Random	1,394,500 cu.yd.		0.58	808,800
Rock riprap	39,500 cu.yd.		4.00	158,000
Gravel fill, pervious				
drain	19,900 cu.yd.		5.25	104,500
Drilling grout holes	4,620 lin.ft.		3.00	13,900
Pressure grouting	3,080 cu.ft.		4.00	12,300
Slope stabilization,				
planting	8.0 acres	1,000.00		8,000
				<u>\$1,981,400</u>
<b>Spillway</b>				
Excavation, unclassified	370,000 cu.yd.		2.00	740,000
Concrete				
Weir and cutoff	1,100 cu.yd.		35.00	38,500
Floor	1,900 cu.yd.		30.00	57,000
Walls	610 cu.yd.		40.00	24,400
Reinforcing steel	371,200 lbs.		0.15	55,700
				<u>915,600</u>
<b>Outlet Works</b>				
Excavation				
Inlet structure	300 cu.yd.		5.00	1,500
Conduit trench	9,030 cu.yd.		6.00	54,200
Concrete				
Inlet structure	220 cu.yd.		60.00	13,200
Conduit encasement	3,010 cu.yd.		40.00	120,400
Reinforcing steel	154,300 lbs.		0.15	23,100

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 43,000 ACRE-FeET  
(Continued)

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
Outlet Works (Continued)				
Miscellaneous metal work	32,000	lbs.	\$ 0.40	\$ 12,800
Steel pipe 60-inch dia.	273,500	lbs.	0.28	76,600
High pressure slide gate			lump sum	25,000
48" Howell-Bunger valve			lump sum	12,000
Control house, etc.			lump sum	<u>9,000</u>
				\$ 347,800
Reservoir				
Land acquisition			lump sum	25,000
Clearing	850 acres		50.00	42,500
State road relocation			lump sum	1,050,000
Access road			lump sum	<u>40,000</u>
				1,157,500
Subtotal				\$4,402,300
Administration and engineering, 10%				\$ 440,200
Contingencies, 15%				660,300
Interest during construction				<u>110,000</u>
TOTAL				\$5,612,800
<b>ANNUAL COSTS</b>				
Interest, 4%				\$ 224,500
Amortization, 40-year sinking fund at 4%				59,000
Operation and maintenance				<u>8,000</u>
TOTAL				\$ 291,500

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 77,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam:	Capacity of reservoir to crest of
3,450 feet, Santa Clara Water	spillway: 77,000 acre-feet
Conservation District datum, 1932	Capacity of spillway with 5-foot
Elevation of crest of spillway:	freeboard: 50,000 second feet
3,430	
Height of dam to spillway crest,	
above stream bed: 230 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	45,000
Diversion tunnel				
16-foot diameter	1,520 lin.ft.	\$	460.00	699,200
Portal excavation	3,550 cu.yd.		1.50	5,300
Concrete plug	370 cu.yd.		30.00	11,100
Diversion of stream and dewatering of foundation		lump sum		20,000
Stripping topsoil	37,400 cu.yd.		0.50	18,700
Foundation excavation				
Abutment	98,100 cu.yd.		1.60	157,000
Channel	80,100 cu.yd.		0.60	48,100
Embankment				
Impervious	1,281,200 cu.yd.		0.80	1,025,000
Random	2,121,800 cu.yd.		0.58	1,230,600
Rock riprap	50,640 cu.yd.		4.00	202,600
Gravel fill, pervious drain	29,400 cu.yd.		5.25	154,400
Drilling grout holes	5,160 lin.ft.		3.00	15,500
Pressure grouting	3,440 cu.ft.		4.00	13,800
Slope stabilization, planting	10.7 acres	1,000.00		<u>10,700</u>
				\$3,657,000
<b>Spillway</b>				
Excavation, unclassified	213,100 cu.yd.		2.00	426,200
Concrete				
Weir and cutoff	1,210 cu.yd.		35.00	42,400
Floor	1,850 cu.yd.		30.00	55,500
Walls	550 cu.yd.		40.00	22,000
Reinforcing steel	281,900 lbs.		0.15	<u>42,300</u>
				588,400
<b>Outlet Works</b>				
Inlet structure concrete	300 cu.yd.		60.00	18,000
Inlet structure excavation	400 cu.yd.		5.00	2,000
Steel pipe 60-inch dia.	322,200 lbs.		0.28	90,200
Reinforcing steel	41,000 lbs.		0.15	6,200
High pressure slide gate		lump sum		25,000



ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 77,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Outlet Works (Continued)				
54" Howell-Bunger valve			lump sum \$	18,000
Miscellaneous metal work	35,000	lbs.	\$ 0.40	14,000
Control house, etc.			lump sum	<u>11,300</u> \$ 184,700
Reservoir				
Land acquisition			lump sum	25,000
Clearing	1,140	acres	50.00	57,000
State road relocation			lump sum	1,050,000
Access road			lump sum	<u>40,000</u> <u>1,172,000</u>
Subtotal				\$5,602,100
Administration and engineering, 10%				\$ 560,200
Contingencies, 15%				840,300
Interest during construction				<u>280,100</u>
TOTAL				\$7,282,700
ANNUAL COSTS				
Interest, 4%				\$ 291,300
Amortization, 40-year sinking fund at 4%				76,600
Operation and maintenance				<u>10,000</u>
TOTAL				\$ 377,900

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam:	Capacity of reservoir to crest of
3,472 feet, Santa Clara Water	spillway: 100,000 acre-feet
Conservation District datum, 1932	Capacity of spillway with 5-foot
Elevation of crest of spillway:	freeboard: 50,000 second-feet
3,452 feet	
Height of dam to spillway crest,	
above stream bed: 252 feet	

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Dam				
Exploration		lump sum	\$	50,000
Diversion tunnel				
16-foot diameter	1,520	lin.ft.	\$ 460.00	699,200
Portal excavation	3,600	cu.yd.	1.50	5,400
Concrete plug	370	cu.yd.	30.00	11,100
Diversion of stream and dewatering of foundation		lump sum		22,000
Stripping topsoil	48,860	cu.yd.	0.50	24,400
Foundation excavation				
Abutment	132,600	cu.yd.	1.60	212,200
Channel	119,200	cu.yd.	0.60	71,500
Embankment				
Impervious	1,534,700	cu.yd.	0.83	1,273,800
Random	3,034,400	cu.yd.	0.60	1,820,600
Rock riprap	64,140	cu.yd.	4.00	256,600
Gravel fill, pervious drain	38,800	cu.yd.	5.25	203,700
Drilling grout holes	5,520	lin.ft.	3.00	16,600
Pressure grouting	3,680	cu.ft.	4.00	14,700
Slope stabilization, planting	13.3	acres	1,000.00	<u>13,300</u>
				\$4,695,100
Spillway				
Excavation, unclassified	185,800	cu.yd.	2.00	371,600
Concrete				
Weir and cutoff	1,230	cu.yd.	35.00	43,100
Floor	1,800	cu.yd.	30.00	54,000
Walls	570	cu.yd.	40.00	22,800
Reinforcing steel	281,400	lbs.	0.15	<u>42,200</u>
				533,700
Outlet Works				
Inlet structure concrete	300	cu.yd.	60.00	18,000
Inlet structure excavation	400	cu.yd.	5.00	2,000
Steel pipe 60-inch dia.	322,200	lbs.	0.28	90,200

ESTIMATED COST OF COLD SPRING DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Outlet Works (Continued)				
Reinforcing steel	41,000	lbs.	\$ 0.15	\$ 6,200
High pressure slide gate			lump sum	25,000
54" Howell-Bunger valve			lump sum	18,000
Miscellaneous metal work	35,000	lbs.	0.40	14,000
Control house, etc.			lump sum	<u>11,300</u>
				\$ 184,700
Reservoir				
Land acquisition			lump sum	25,000
Clearing	1,290	acres	50.00	64,500
State road relocation			lump sum	1,050,000
Access road			lump sum	<u>40,000</u>
				<u>1,179,500</u>
Subtotal				\$6,593,000
Administration and engineering, 10%				\$ 659,300
Contingencies, 15%				989,000
Interest during construction				<u>329,700</u>
TOTAL				\$8,571,000
ANNUAL COSTS				
Interest, 4%				\$ 342,800
Amortization, 40-year sinking fund at 4%				90,200
Operation and maintenance				<u>12,500</u>
TOTAL				\$ 445,500



ESTIMATED COST OF TOPATOPA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 2,395 feet, U.S.G.S. datum	Height of dam to top of gates, above stream bed: 280 feet
Elevation of crest of chute spill- way: 2,360 feet	Capacity of reservoir to top of gates: 50,000 acre-feet
Elevation of crest of overpour spillway: 2,380 feet	Capacity of spillways with 5-foot freeboard: 82,000 second-feet
Elevation of top of gates, chute spillway: 2,380 feet	

Item	:	Quantity	:	Unit	:	price	:	Cost
<b>CAPITAL COSTS</b>								
<b>Dam</b>								
Concrete		287,000 cu.yd.	\$	18.00		\$5,166,000		
Excavation		100,000 cu.yd.		3.00		300,000		
Drilling grout holes		9,000 lin.ft.		3.00		27,000		
Pressure grouting		7,000 cu.ft.		4.00		28,000		
Diversion of stream				lump sum		50,000		
Exploration				lump sum		<u>35,000</u>		\$5,606,000
<b>Chute spillway</b>								
Concrete		4,500 cu.yd.		40.00		180,000		
Excavation		155,000 cu.yd.		4.00		620,000		
Reinforcing steel		380,000 lbs.		0.15		57,000		
Gates and hoists		3 each		25,000.00		<u>75,000</u>		932,000
Outlet Works				lump sum				60,000
<b>Reservoir</b>								
Land acquisition				lump sum		25,000		
Roads to dam				lump sum		400,000		
Clearing				lump sum		<u>20,000</u>		<u>445,000</u>
Subtotal								\$7,043,000
Administration and engineering, 10%						\$ 704,000		
Contingencies, 15%						1,056,000		
Interest during construction						<u>352,000</u>		
TOTAL								\$9,155,000

**ANNUAL COSTS**

Interest, 4%	\$ 366,200
Amortization, 40-year sinking fund at 4%	96,300
Operation and maintenance	<u>20,000</u>
TOTAL	\$ 482,500

ESTIMATED COST OF TOPATOPA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 75,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 2,437 feet, U.S.G.S. datum	Height of dam to top of gates, above stream bed: 322 feet
Elevation of crest of chute spillway: 2,400 feet	Capacity of reservoir to top of gates: 75,000 acre-feet
Elevation of crest of overpour spillway: 2,420 feet	Capacity of spillways with 5-foot freeboard: 82,000 second-feet
Elevation of top of gates, chute spillway: 2,420 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Concrete	412,000 cu.yd.	\$	18.00	\$7,416,000
Excavation	190,000 cu.yd.		3.00	570,000
Drilling grout holes	11,000 lin.ft.		3.00	33,000
Pressure grouting	9,000 cu.ft.		4.00	36,000
Diversion of stream			lump sum	50,000
Exploration			lump sum	35,000
				<u>\$8,140,000</u>
<b>Chute spillway</b>				
Concrete	4,300 cu.yd.		40.00	172,000
Excavation	146,000 cu.yd.		4.00	584,000
Reinforcing steel	360,000 lbs.		0.15	54,000
Gates and hoists	3 each	25,000.00		75,000
				<u>885,000</u>
<b>Outlet Works</b>				
			lump sum	60,000
<b>Reservoir</b>				
Land acquisition			lump sum	25,000
Roads to dam			lump sum	400,000
Clearing			lump sum	30,000
				<u>455,000</u>
<b>Suhtotal</b>				<b>\$9,540,000</b>
Administration and engineering, 10%				\$ 954,000
Contingencies, 15%				1,431,000
Interest during construction				<u>596,000</u>
<b>TOTAL</b>				<b>\$12,521,000</b>
<b>ANNUAL COSTS</b>				
Interest, 4%				\$ 500,800
Amortization, 40-year sinking fund at 4%				131,700
Operating and maintenance				<u>20,000</u>
<b>TOTAL</b>				<b>\$ 652,500</b>

ESTIMATED COST OF TOPATOPIA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 2,470 feet, U.S.G.S. datum	Height of dam to top of gates, above stream bed: 355 feet
Elevation of crest of chute spillway: 2,435 feet	Capacity of reservoir to top of gates: 100,000 acre-feet
Elevation of crest of overpour spillway: 2,455 feet	Capacity of spillways with 5-foot freeboard: 82,000 second-feet
Elevation of top of gates, chute spillway: 2,455 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Concrete	522,000	cu.yd.	\$ 18.00	\$9,396,000
Excavation	275,000	cu.yd.	3.00	825,000
Drilling grout holes	13,000	lin ft.	3.00	39,000
Pressure grouting	11,000	cu.ft.	4.00	44,000
Diversion of stream		lump sum		50,000
Exploration		lump sum		<u>35,000</u>
				\$10,389,000
<b>Chute spillway</b>				
Concrete	4,100	cu.yd.	40.00	164,000
Excavation	122,000	cu.yd.	4.00	488,000
Reinforcing steel	350,000	lbs.	0.15	52,500
Gates and hoists	3	each	25,000.00	<u>75,000</u>
				779,500
<b>Outlet Works</b>				
		lump sum		60,000
<b>Reservoir</b>				
Land acquisition		lump sum		62,500
Roads to dam		lump sum		400,000
Clearing		lump sum		<u>40,000</u>
				502,500
Subtotal				\$11,731,000
Administration and engineering, 10%				\$ 1,173,000
Contingencies, 15%				1,760,000
Interest during construction				<u>880,000</u>
TOTAL				\$15,544,000

**ANNUAL COSTS**

Interest, 4%	\$ 621,800
Amortization, 40-year sinking fund at 4%	163,500
Operation and maintenance	<u>20,000</u>
TOTAL	\$ 805,300



ESTIMATED COST OF HAMMEL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 25,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,125 feet, U.S.G.S. datum	Capacity of reservoir to top of gates: 25,000 acre-feet
Elevation of top of gates: 1,120 feet	Capacity of spillway with 5-foot freeboard: 90,000 second-feet
Height of dam to top of gates, above stream bed: 330 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum \$	90,000
Diversion tunnel			
7-foot diameter	490 lin.ft.	\$ 140.00	68,600
Portal excavation	2,000 cu.yd.	2.00	4,000
Concrete plug	40 cu.yd.	30.00	1,200
Diversion of stream and dewatering of foundation		lump sum	40,000
Stripping	179,400 cu.yd.	3.00	538,200
Mass concrete	530,700 cu.yd.	15.00	7,960,500
Cooling concrete	530,700 cu.yd.	0.50	265,300
Parapet wall concrete	180 cu.yd.	50.00	9,000
Drilling grout holes	3,300 lin.ft.	4.00	13,200
Pressure grouting	2,200 cu.ft.	3.00	6,600
			<u>\$8,996,600</u>
<b>Spillway</b>			
Reinforced concrete			
Walls	1,490 cu.yd.	40.00	59,600
Piers	740 cu.yd.	50.00	37,000
Gates and hoists	928,000 lbs.	0.32	297,000
Reinforcing steel	549,000 lbs.	0.15	82,300
Bridge		lump sum	20,000
			<u>495,900</u>
<b>Outlet Works</b>			
Ring seal gates	120,000 lbs.	0.45	54,000
Needle valve 48-inch dia.	32,000 lbs.	0.55	17,600
Steel pipe 54-inch dia.	75,000 lbs.	0.28	21,000
Trashrack steel	90,000 lbs.	0.40	36,000
Miscellaneous metal work	371,000 lbs.	0.40	148,400
			<u>277,000</u>
<b>Reservoir</b>			
Access road	2 miles	50,000.00	100,000
Clearing	210 acres	150.00	31,500
Land and improvements		lump sum	12,500
			<u>144,000</u>
Subtotal			\$9,913,500
Administration and engineering, 10%			\$ 991,300
Contingencies, 15%			1,487,000
Interest during construction			<u>495,700</u>
TOTAL			<u>\$12,887,500</u>

ESTIMATED COST OF HAMMEL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 25,000 ACRE-FEET  
(Continued)

Item	: Quantity	: Unit price	: Cost
ANNUAL COSTS			
Interest, 4%			\$ 515,500
Amortization, 40-year sinking fund at 4%			135,600
Operation and maintenance			<u>15,000</u>
TOTAL			\$ 666,100

ESTIMATED COST OF HAMMEL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FeET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,223 feet, U.S.G.S. datum	Capacity of reservoir to top of gates: 50,000 acre-feet
Elevation of top of gates: 1,218 feet	Capacity of spillway with 5-foot freeboard: 90,000 second-feet
Height to top of gates, above stream bed: 428 feet	

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
Dam				
Exploration		lump sum	\$	110,000
Diversion tunnel				
7-foot diameter	560 lin.ft.	\$	140.00	78,400
Portal excavation	2,000 cu.yd.		2.00	4,000
Concrete plug	40 cu.yd.		30.00	1,200
Diversion of stream and de-watering of foundation		lump sum		40,000
Stripping	286,100 cu.yd.		3.00	858,300
Mass concrete	1,067,900 cu.yd.		15.00	16,018,500
Cooling concrete	1,067,900 cu.yd.		0.50	533,900
Parapet wall concrete	320 cu.yd.		50.00	16,000
Drilling grout holes	4,920 lin.ft.		4.00	19,700
Pressure grouting	3,280 cu.ft.		3.00	9,800
				<u>\$17,689,80</u>
Spillway				
Reinforced concrete				
Walls	2,120 cu.yd.		40.00	84,800
Piers	740 cu.yd.		50.00	37,000
Gates and hoist	928,000 lbs.		0.32	297,000
Reinforcing steel	725,000 lbs.		0.15	108,700
Bridge		lump sum		20,000
				<u>547,50</u>
Outlet Works				
Ring seal gates	120,000 lbs.		0.45	54,000
Needle valve 48-inch dia.	32,000 lbs.		0.55	17,600
Steel pipe 54-inch dia.	124,000 lbs.		0.28	34,700
Trashrack steel	90,000 lbs.		0.40	36,000
Miscellaneous metal work	747,500 lbs.		0.40	299,000
				<u>441,30</u>
Reservoir				
Access road	2 miles		50,000.00	100,000
Clearing	320 acres		150.00	48,000
Land and improvements		lump sum		12,500
				<u>160,50</u>
Subtotal				<u>\$18,839,10</u>



ESTIMATED COST OF HAMMEL DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Administration and engineering, 10%			\$ 1,883,900
Contingencies, 15%			2,825,900
Interest during construction			<u>942,000</u>
<b>TOTAL</b>			<b>\$24,490,900</b>
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 979,600
Amortization, 40-year sinking fund at 4%			257,600
Operation and maintenance			<u>15,000</u>
<b>TOTAL</b>			<b>\$ 1,252,200</b>

ESTIMATED COST OF UPPER BLUE POINT DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,320 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 50,000 acre-feet
Elevation of crest of spillway: 1,295 feet	Capacity of spillway with 5-foot freeboard: 100,000 second-feet
Height of dam to spillway crest, above stream bed: 205 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	50,000
Diversion tunnel				
20-foot diameter	1,250	lin.ft.	\$ 500.00	625,000
Portal excavation	4,000	cu.yd.	0.70	2,800
Concrete plug	730	cu.yd.	30.00	21,900
Diversion of stream and dewatering of foundation		lump sum		20,000
Stripping topsoil	53,000	cu.yd.	0.40	21,200
Foundation excavation	679,500	cu.yd.	0.90	611,600
Embankment				
Impervious	1,867,500	cu.yd.	0.70	1,307,300
Pervious	3,118,900	cu.yd.	0.50	1,559,500
Rock riprap	77,000	cu.yd.	4.00	308,000
Drilling grout holes	6,660	lin.ft.	3.00	20,000
Pressure grouting	4,440	cu.ft.	4.00	17,800
				<u>\$4,565,100</u>
<b>Spillway</b>				
Excavation	599,900	cu.yd.	2.25	1,349,800
Concrete				
Weir and cutoff	1,860	cu.yd.	30.00	55,800
Floor	4,080	cu.yd.	25.00	102,000
Walls	1,840	cu.yd.	40.00	73,600
Reinforcing steel	624,100	lbs.	0.15	93,600
				<u>1,674,800</u>
<b>Outlet Works</b>				
Tower concrete	660	cu.yd.	80.00	52,800
Tower excavation	400	cu.yd.	5.00	2,000
Steel pipe 72-in. dia.	336,600	lbs.	0.28	94,200
Tower inlet valve				
36-in. dia.	4	each	3,600.00	14,400
Howell-Bunger valve				
48-in. dia.	1	each	12,000.00	12,000
Needle valve 48-in. dia.	1	each	18,000.00	18,000
Sluice gate		lump sum		25,000
Miscellaneous metal work	32,000	lbs.	0.40	12,800
Control house, etc.		lump sum		<u>10,000</u>
				<u>241,200</u>

ESTIMATED COST OF UPPER BLUE POINT DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-Feet  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Reservoir			
Land acquisition		lump sum \$	33,300
Clearing	640 acres	\$ 50.00	32,000
Access Road		lump sum	<u>15,000</u>
			\$ 80,300
Subtotal			\$6,561,400
Administration and engineering, 10%			\$ 656,200
Contingencies, 15%			984,200
Interest during construction			<u>328,000</u>
TOTAL			\$8,529,800
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 341,200
Amortization, 40-year sinking fund at 4%			89,700
Operation and maintenance			<u>7,500</u>
TOTAL			\$ 438,400



ESTIMATED COST OF BLUE POINT DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,305 feet, U.S.G.S. Datum	Capacity of reservoir to crest of spillway: 50,000 acre-feet
Elevation of crest of spillway: 1,280 feet	Capacity of spillway with 5-foot freeboard: 100,000 second-feet
Height of dam to spillway crest, above stream bed: 215 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	50,000
Diversion of stream and dewatering of foundation		lump sum		40,000
Stripping topsoil	33,200	cu.yd.	\$ 0.40	13,300
Foundation excavation	733,100	cu.yd.	0.90	659,800
<b>Embankment</b>				
Impervious	1,435,800	cu.yd.	0.70	1,005,100
Pervious	2,061,900	cu.yd.	0.50	1,031,000
Rock riprap	55,400	cu.yd.	4.00	221,600
Drilling grout holes	4,830	lin.ft.	3.00	14,500
Pressure grouting	3,220	cu.ft.	4.00	12,900
				<u>\$3,048,200</u>
<b>Spillway</b>				
Portal excavation	300,000	cu.yd.	2.25	675,000
Tunnel excavation	60,000	cu.yd.	15.00	900,000
<b>Concrete</b>				
Weir	4,500	cu.yd.	30.00	135,000
Walls and paving	2,500	cu.yd.	40.00	100,000
Tunnel lining	12,000	cu.yd.	50.00	600,000
Reinforcing steel	2,000,000	lbs.	0.15	300,000
				<u>2,710,000</u>
<b>Outlet Works</b>				
<b>Excavation</b>				
Tower foundation	380	cu.yd.	5.00	1,900
Conduit trench	5,080	cu.yd.	6.00	30,500
<b>Concrete</b>				
Tower	660	cu.yd.	80.00	52,800
Pipe encasement	3,340	cu.yd.	40.00	133,600
Reinforcing steel	283,400	lbs.	0.15	42,500
Steel pipe, 72-inch dia.	359,600	lbs.	0.28	100,700
Gate valve 36-inch dia.	4	each	3,600.00	14,400
Howell-Bunger valve 48-inch dia.	1	each	12,000.00	12,000
Needle valve 48-inch dia.	1	each	18,000.00	18,000
Sluice gate	1	each	20,000.00	20,000
Miscellaneous metal work	33,000	lbs.	0.40	13,200
Control house, etc.		lump sum		<u>10,000</u>
				449,600

ESTIMATED COST OF BLUE POINT DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 50,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Reservoir			
Land acquisition		lump sum \$	33,300
Clearing	640 acres	\$ 50.00	32,000
Access Road		lump sum	<u>12,200</u> \$ 77,500
Subtotal			\$6,285,300
Administration and engineering, 10%			\$ 628,500
Contingencies, 15%			942,800
Interest during construction			<u>314,300</u>
TOTAL			\$8,170,900
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 326,800
Amortization, 40-year sinking fund at 4%			86,000
Operation and maintenance			<u>7,500</u>
TOTAL			\$ 420,300

ESTIMATED COST OF DEVIL CANYON DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,245 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 100,000 acre-feet
Elevation of crest of spillway: 1,220 feet	Capacity of spillway with 5-foot freeboard: 102,00 second-feet
Height of dam to spillway crest, above stream bed: 240 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum \$	40,000
Diversion tunnel			
21-foot diameter	1,750 lin.ft.	\$ 510.00	892,500
Portal excavation	13,300 cu.yd.	1.50	19,900
Concrete plug	730 cu.yd.	30.00	21,900
Diversion of stream and dewatering of foundation		lump sum	50,000
Stripping topsoil	57,200 cu.yd.	0.40	22,900
Foundation excavation			
Abutment	105,300 cu.yd.	1.40	147,400
Channel	905,000 cu.yd.	0.60	543,000
Embankment			
Impervious	2,599,400 cu.yd.	0.65	1,689,600
Pervious	3,764,100 cu.yd.	0.45	1,693,800
Rock riprap	80,000 cu.yd.	4.00	320,000
Drilling grout holes	6,360 lin.ft.	3.00	19,100
Pressure grouting	4,240 cu.ft.	4.00	17,000
			<u>\$5,477,100</u>
<b>Spillway</b>			
Excavation	1,288,300 cu.yd.	2.00	2,576,600
Concrete			
Weir and cutoff	5,220 cu.yd.	35.00	182,700
Floor	8,460 cu.yd.	30.00	253,800
Walls	5,180 cu.yd.	40.00	207,200
Reinforcing steel	1,573,700 lbs.	0.15	236,100
			<u>3,456,400</u>
<b>Outlet Works</b>			
Inlet structure concrete	300 cu.yd.	60.00	18,000
Inlet structure excavation	400 cu.yd.	5.00	2,000
Steel pipe 72-in. dia.	450,100 lbs.	0.28	126,000
Reinforcing steel	30,000 lbs.	0.15	4,500
High pressure slide gate		lump sum	25,000
Needle valve 60-in. dia.	1 each	27,500.00	27,500
Miscellaneous metal work	32,000 lbs.	0.40	12,800
Control house, etc.		lump sum	10,000
			<u>225,800</u>



ESTIMATED COST OF DEVIL CANYON DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Reservoir			
Land acquisition		lump sum \$	110,300
Clearing	1,050 acres	\$ 50.00	<u>52,500</u> \$ 162,800
Subtotal			\$9,322,100
Administration and engineering, 10%			\$ 932,200
Contingencies, 15%			<u>1,398,300</u>
Interest during construction			<u>466,100</u>
TOTAL			\$12,118,700

ANNUAL COSTS

Interest, 4%	\$ 484,700
Amortization, 40-year sinking fund at 4%	127,500
Operation and maintenance	<u>12,500</u>
TOTAL	\$ 624,700

ESTIMATED COST OF DEVIL CANYON DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 150,000 ACRE-FeET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,290 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 150,000 acre-feet
Elevation of crest of spillway: 1,265 feet	Capacity of spillway with 5-foot freeboard: 102,000 second-feet
Height of dam to spillway crest, above stream bed: 285 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	40,000
Diversion tunnel				
21-foot diameter	2,130 lin.ft.	\$	510.00	1,086,300
Portal excavation	12,000 cu.yd.		1.50	18,000
Concrete plug	730 cu.yd.		30.00	21,900
Diversion of stream and dewatering of foundation		lump sum		50,000
Stripping topsoil	91,860 cu.yd.		0.40	36,700
Foundation excavation				
Abutment	104,400 cu.yd.		1.40	146,200
Channel	1,036,300 cu.yd.		0.60	621,800
Embankment				
Impervious	3,421,500 cu.yd.		0.65	2,224,000
Pervious	6,467,400 cu.yd.		0.45	2,910,300
Rock riprap	112,840 cu.yd.		4.00	451,400
Drilling grout holes	7,080 lin.ft.		3.00	21,200
Pressure grouting	4,720 cu.ft.		4.00	18,900
				<u>\$7,646,700</u>
<b>Spillway</b>				
Excavation	1,280,100 cu.yd.		2.00	2,560,200
Concrete				
Weir and cutoff	4,250 cu.yd.		35.00	148,800
Floor	10,520 cu.yd.		30.00	315,600
Walls	5,490 cu.yd.		40.00	219,600
Reinforcing steel	1,727,800 lbs.		0.15	259,200
				<u>3,503,400</u>
<b>Outlet Works</b>				
Tower concrete	850 cu.yd.		80.00	68,000
Tower excavation	400 cu.yd.		5.00	2,000
Steel pipe 72-inch dia.	673,200 lbs.		0.28	188,500
Tower inlet valves 36-in. dia.	5 each		3,600.00	18,000
Howell-Bunger valve, 48-in. dia.	1 each		12,000.00	12,000
Needle valve, 48-in. dia.	1 each		18,000.00	18,000
Sluice gate			lump sum	20,000
Miscellaneous metal work	40,000 lbs.		0.40	16,000
Control house, etc.			lump sum	<u>10,000</u>
				352,500

ESTIMATED COST OF DEVIL CANYON DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 150,000 ACRF-Feet  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Reservoir			
Land acquisition		lump sum \$	110,300
Clearing	1,500 acres	\$ 50.00	<u>75,000</u> \$ 185,300
Subtotal			\$11,687,900
Administration and engineering, 10%			\$ 1,168,800
Contingencies, 15%			1,753,200
Interest during construction			<u>876,600</u>
TOTAL			\$15,486,500
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 619,500
Amortization, 40-year sinking fund at 4%			162,900
Operation and maintenance			<u>15,700</u>
TOTAL			\$ 798,100



ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR WITH  
STORAGE CAPACITY OF 50,000 ACRE-FEET  
(Based on prices prevailing in spring 1953)

Elevation of crest of dam: 1,030 feet	Capacity of reservoir to crest of
Elevation of crest of spillway: 1,010 feet	spillway: 50,000 acre-feet
Height of dam to spillway crest, above stream bed: 140 feet	Capacity of spillway with 5-foot freeboard: 103,000 second-feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum	\$ 50,000
Diversion of stream and dewatering of foundation		lump sum	50,000
Stripping topsoil	30,700 cu.yd.	\$ 0.40	12,300
Foundation excavation			
Abutment	29,400 cu.yd.	1.40	41,200
Channel	886,400 cu.yd.	0.55	487,500
Excavation for embankment			
From borrow pits	1,686,600 cu.yd.	0.47	792,700
From stream bed	838,700 cu.yd.	0.36	301,900
Embankment			
Impervious	1,466,600 cu.yd.	0.18	264,000
Pervious	1,571,300 cu.yd.	0.12	188,600
Rock riprap	41,100 cu.yd.	4.00	164,400
Drilling grout holes	6,240 lin.ft.	3.00	18,700
Pressure grouting	4,160 cu. ft.	4.00	16,600
			<u>\$2,387,900</u>
<b>Spillway</b>			
Excavation	1,598,100 cu.yd.	0.90	1,438,300
Concrete			
Weir and cutoff	3,290 cu.yd.	35.00	115,200
Floor	8,590 cu.yd.	30.00	257,700
Walls	3,010 cu.yd.	40.00	120,400
Reinforcing steel	1,199,800 lbs.	0.15	180,000
			<u>2,111,600</u>
<b>Outlet Works</b>			
Excavation			
Inlet Structure	300 cu.yd.	5.00	1,500
Conduit Trench	5,250 cu.yd.	6.00	31,500
Concrete			
Inlet structure	220 cu.yd.	60.00	13,200
Conduit encasement	1,750 cu.yd.	40.00	70,000
Reinforcing steel	91,200 lbs.	0.15	13,700
Steel pipe 60-inch dia.	159,000 lbs.	0.28	44,500
Miscellaneous metal work	32,000 lbs.	0.40	12,800
High pressure slide gate		lump sum	25,000
Needle valve 54-inch dia.		lump sum	20,000
Control house, etc.		lump sum	10,000
			<u>242,200</u>

ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR WITH  
STORAGE CAPACITY OF 50,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Reservoir			
Land acquisition		lump sum	\$ 447,000
Clearing	1,030 acres	\$ 50.00	51,500
Road relocation and oil well damage		lump sum	<u>350,000</u> <u>\$848,500</u>
Subtotal			\$5,590,200
Administration and engineering, 10%			\$ 559,000
Contingencies, 15%			838,500
Interest during construction			<u>139,800</u>
TOTAL			\$7,127,500

ANNUAL COSTS

Interest, 4%	\$285,100
Amortization, 40-year sinking fund at 4%	75,000
Operation and maintenance	<u>9,000</u>
TOTAL	\$369,100

ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR WITH  
STORAGE CAPACITY OF 75,000 ACRE-FEET  
(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,055 feet	Capacity of reservoir to crest of spillway: 75,000 acre-feet
Elevation of crest of spillway: 1,035 feet	Capacity of spillway with 5-foot freeboard: 103,000 second-feet
Height of dam to spillway crest, above stream bed: 165 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$	50,000
Diversion tunnel				
22-foot diameter	1,080 lin.ft.	\$	530.00	572,400
Portal excavation	18,000 cu.yd.		1.50	27,000
Concrete plug	800 cu.yd.		30.00	24,000
Diversion of stream and dewatering of foundation		lump sum		60,000
Stripping topsoil	42,600 cu.yd.		0.40	17,000
Foundation excavation				
Abutment	37,100 cu.yd.		1.40	51,900
Channel	989,300 cu.yd.		0.55	544,100
Excavation for embankment				
From borrow pits	2,198,200 cu.yd.		0.47	1,033,200
From streambed	1,794,400 cu.yd.		0.36	646,000
Embankment				
Impervious	1,911,500 cu.yd.		0.18	344,100
Pervious	2,615,500 cu.yd.		0.12	313,900
Rock riprap	59,700 cu.yd.		4.00	238,800
Drilling grout holes	6,960 lin.ft.		3.00	20,900
Pressure grouting	4,640 cu.ft.		4.00	18,600
				<u>\$3,961,900</u>
<b>Spillway</b>				
Excavation	1,034,100 cu.yd.		0.80	827,300
Concrete				
Weir and cutoff	3,290 cu.yd.		35.00	115,200
Floor	8,230 cu.yd.		30.00	246,900
Walls	2,820 cu.yd.		40.00	112,800
Reinforcing steel	1,153,100 lbs.		0.15	173,000
				<u>1,475,200</u>
<b>Outlet Works</b>				
Inlet structure concrete	290 cu.yd.		60.00	17,400
Inlet structure excavation	390 cu.yd.		5.00	2,000
Steel pipe 72-inch dia.	280,500 lbs.		0.28	78,500
Reinforcing steel	27,300 lbs.		0.15	4,100
High pressure slide gate		lump sum		25,000
Needle valve 60-inch dia.	1 each		27,500.00	27,500
Miscellaneous metal work	32,000 lbs.		0.40	12,800
Control house, etc.		lump sum		10,000
				<u>177,200</u>



ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 75,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Reservoir			
Land acquisition		lump sum	\$ 447,000
Clearing	1,270 acres	\$ 50.00	63,500
Road relocation and oil well damage		lump sum	<u>350,000</u>
			\$860,500
Subtotal			\$6,474,900
Administration and engineering, 10%			\$ 647,500
Contingencies, 15%			971,200
Interest during construction			<u>323,700</u>
TOTAL			\$8,417,300
<b>ANNUAL COSTS</b>			
Interest, 4%			\$336,700
Amortization, 40-year sinking fund at 4%			88,500
Operation and maintenance			<u>10,000</u>
TOTAL			\$435,200

ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-Feet

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,077 feet, U.S.G.S. datum	Capacity of reservoir to crest of spillway: 100,000 acre-feet
Elevation of crest of spillway: 1,057 feet	Capacity of spillway with 5-foot freeboard: 103,000 second-feet
Height of dam to spillway crest, above stream bed: 187 feet	

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Dam</b>			
Exploration		lump sum \$	50,000
Diversion tunnel			
22-foot diameter	1,270 lin.ft.	\$ 530.00	673,100
Portal excavation	19,800 cu.yd.	1.50	29,700
Concrete plug	890 cu.yd.	30.00	26,700
Diversion of stream and dewatering of foundation		lump sum	70,000
Stripping topsoil	92,300 cu.yd.	0.40	36,900
Foundation excavation			
Abutment	57,700 cu.yd.	1.40	80,800
Channel	1,018,600 cu.yd.	0.55	560,200
Excavation for embankment			
From borrow pits	2,458,200 cu.yd.	0.47	1,155,400
From stream bed	2,492,500 cu.yd.	0.36	897,300
Embankment			
Impervious	2,137,600 cu.yd.	0.18	384,800
Pervious	3,290,500 cu.yd.	0.12	394,900
Rock riprap	75,740 cu.yd.	4.00	303,000
Drilling grout holes	7,260 lin.ft.	3.00	21,800
Pressure grouting	4,840 cu.ft.	4.00	19,400
			<u>\$4,704,000</u>
<b>Spillway</b>			
Excavation	699,100 cu.yd.	0.70	489,400
Concrete			
Weir and cutoff	3,290 cu.yd.	35.00	115,200
Floor	8,950 cu.yd.	30.00	268,500
Walls	3,190 cu.yd.	40.00	127,600
Reinforcing steel	1,245,700 lbs.	0.15	186,900
			<u>1,187,600</u>
<b>Outlet Works</b>			
Inlet structure concrete	290 cu.yd.	60.00	17,400
Inlet structure excavation	390 cu.yd.	5.00	2,000
Steel pipe 72-inch dia.	295,800 lbs.	0.28	82,800
Reinforcing steel	30,000 lbs.	0.15	4,500
High pressure slide gate		lump sum	25,000
Needle valve 60-inch dia.	1 each	27,500.00	27,500
Miscellaneous metal work	32,000 lbs.	0.40	12,800
Control house, etc.		lump sum	10,000
			<u>182,000</u>

ESTIMATED COST OF SANTA FELICIA DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 100,000 ACRE-FEET  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<b>Reservoir</b>			
Land acquisition		lump sum \$	447,000
Clearing	1,490 acres	\$ 50.00	74,500
Road relocation and oil well damage		lump sum	<u>350,000</u> \$ 871,500
Subtotal			\$6,945,100
Administration and engineering, 10%			\$ 694,500
Contingencies, 15%			1,041,800
Interest during construction			<u>347,300</u>
TOTAL			\$9,028,700

**ANNUAL COSTS**

Interest, 4%	\$ 361,100
Amortization, 40-year sinking fund at 4%	95,000
Operation and maintenance	<u>12,500</u>
TOTAL	\$ 468,600



ESTIMATED COST OF DISTRIBUTION SYSTEM  
FROM CASITAS RESERVOIR

(Based on prices prevailing in spring of 1953)

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<u>Main Feeder - Casitas Reservoir to Foster Park</u>				
Excavation and backfill	12,900 lin.ft.	\$	2.80	\$ 36,100
Furnish and install 36-inch diameter reinforced concrete pipe	12,900 lin.ft.		16.25	209,600
Ventura River crossing	1,100 lin.ft.		26.75	29,400
Gate valves		lump sum		4,000
Line meters	2 each		4,000.00	8,000
Blowoff valves	2 each		500.00	1,000
Air valves	2 each		400.00	800
Chlorinator structure		lump sum		10,000
Chlorinator equipment		lump sum		10,500
Road surfacing	12,900 lin.ft.		1.00	12,900
Concrete in structures	220 cu.yd.		65.00	14,300
Miscellaneous metal	2,500 lbs.		0.65	1,600
Fire hydrants	4 each		150.00	600
Right of way		lump sum		5,000
				<u>\$ 343,800</u>
<u>Eastside Conduit - Foster Park to Lacrosse</u>				
Excavation and backfill	8,700 lin.ft.		2.15	18,700
Furnish and install 27-inch diameter concrete cylinder pipe	8,700 lin.ft.		11.85	103,100
Creek crossing	300 lin.ft.		20.75	6,200
Gate valve - 18-inch dia.	1 each		1,000.00	1,000
Blowoff valves		lump sum		400
Air valves	2 each		300.00	600
Service outlets	5 each		150.00	800
Concrete structures	50 cu.yd.		65.00	3,300
Miscellaneous metal	1,000 lbs.		0.65	700
Road surfacing	8,700 lin.ft.		0.85	7,400
Fire hydrants	2 each		150.00	300
Right of way		lump sum		1,000
				<u>143,500</u>
<u>Eastside Conduit - Lacrosse to Baldwin Road</u>				
Excavation and backfill	18,000 lin.ft.		1.86	33,500
Furnish and install 24-inch diameter concrete cylinder pipe	18,000 lin.ft.		10.25	184,500
Gate valves - 18-inch dia.	3 each		1,000.00	3,000
Line meter		lump sum		2,900
Blowoff valves	2 each		400.00	800
Air valves	2 each		300.00	600
Service outlets	5 each		150.00	800
Concrete structures	80 cu.yd.		65.00	5,200
Miscellaneous metal	2,000 lbs.		0.65	1,300

ESTIMATED COST OF DISTRIBUTION SYSTEM  
FROM CASITAS RESERVOIR  
(Continued)

Item	Quantity	Unit price	Cost
<b>PITAL COSTS</b>			
<b>Outside Conduit - Lacrosse to Baldwin Road (Continued)</b>			
Road surfacing	7,500 lin.ft.	\$ 0.80	\$ 6,000
Fire hydrants	8 each	150.00	1,200
Reservoir		lump sum	35,000
Pumping plant		lump sum	32,200
Right of way		lump sum	15,000
			<u>\$ 322,000</u>
<b>Outside Conduit - Baldwin Road to Fairview Wye</b>			
Excavation and backfill	11,400 lin.ft.	1.00	11,400
Furnish and install 16-inch diameter concrete cylinder pipe	11,400 lin.ft.	6.25	71,200
Gate valves - 12-inch dia.	2 each	450.00	900
Blowoff valves	3 each	200.00	600
Air valves	2 each	300.00	600
Service outlets	5 each	150.00	800
Concrete structures	80 cu.yd.	65.00	5,200
Miscellaneous metal	1,000 lbs.	0.65	600
Road surfacing	9,000 lin.ft.	0.60	5,400
Fire hydrants	7 each	150.00	1,000
Pumping plant		lump sum	27,000
Right of way		lump sum	4,000
			<u>128,700</u>
<b>Reek Road Conduit - Lacrosse to Terminal Reservoir</b>			
Excavation and backfill	42,800 lin.ft.	1.00	42,800
Furnish and install 16-inch diameter concrete cylinder pipe	42,800 lin.ft.	6.25	267,500
Gate valves - 12-inch dia.	8 each	450.00	3,600
Line meter		lump sum	2,000
Blowoff valves	4 each	200.00	800
Air valves	8 each	300.00	2,400
Service outlets	14 each	150.00	2,100
Concrete structures	150 cu.yd.	65.00	9,800
Miscellaneous metal	3,300 lbs.	0.65	2,100
Road surfacing	24,400 lin.ft.	0.60	14,600
Fire hydrants	10 each	150.00	1,500
Highway crossing		lump sum	2,500
Reservoir		lump sum	35,000
Pumping plant		lump sum	34,200
Right of way		lump sum	7,000
			<u>427,900</u>
<b>Upper Ojai Conduit</b>			
Excavation and backfill	10,200 lin.ft.	0.80	8,200
Furnish and install 12-inch diameter concrete cylinder pipe	10,200 lin.ft.	4.85	49,500

ESTIMATED COST OF DISTRIBUTION SYSTEM  
FROM CASITAS RESERVOIR  
(Continued)

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<u>Upper Ojai Conduit (Continued)</u>				
Gate valves - 10-inch dia.	2	each	\$ 350.00	\$ 700
Line meter			lump sum	1,800
Blowoff valves	2	each	200.00	400
Air valves	2	each	300.00	600
Service outlets	5	each	150.00	800
Concrete structures	75	cu.yd.	65.00	4,900
Miscellaneous metal	1,000	lbs.	0.65	600
Road surfacing	4,200	lin.ft.	0.55	2,300
Fire hydrants	3	each	150.00	400
Pumping plant			lump sum	15,700
Right of way			lump sum	2,500
				<u>\$ 88,400</u>
<u>Cross Tie to Grand Avenue</u>				
Excavation and backfill	4,500	lin.ft.	0.80	3,600
Furnish and install 12-inch diameter concrete cylinder pipe	4,500	lin.ft.	4.85	21,800
Gate valves - 10-inch dia.	2	each	350.00	700
Line meter			lump sum	1,800
Blowoff valves			lump sum	200
Air valves	2	each	300.00	600
Service outlets	3	each	150.00	400
Concrete structures	20	cu.yd.	65.00	1,300
Concrete pipe anchors	20	cu.yd.	30.00	600
Miscellaneous metal	1,000	lbs.	0.65	600
Road surfacing	4,500	lin.ft.	0.55	2,500
Fire hydrants	3	each	150.00	400
Right of way			lump sum	500
				<u>35,000</u>
<u>Baldwin Road - Santa Ana Conduit</u>				
Excavation and backfill	11,800	lin.ft.	1.00	11,800
Furnish and install 14-inch diameter concrete cylinder pipe	11,800	lin.ft.	5.45	64,300
Ventura River crossing	1,600	lin.ft.	10.70	17,100
Gate valves - 12-inch dia.	3	each	450.00	1,400
Line meter			lump sum	1,800
Blowoff valves	2	each	200.00	400
Air valves	3	each	300.00	900
Service connections	4	each	150.00	600
Concrete structures	60	cu.yd.	65.00	3,900
Miscellaneous metal	1,500	lbs.	0.65	1,000
Road surfacing	8,800	lin.ft.	0.60	5,300
Fire Hydrants	3	each	150.00	400



ESTIMATED COST OF DISTRIBUTION SYSTEM  
FROM CASITAS RESERVOIR  
(Continued)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<u>Eldwin Road - Santa Ana Conduit (Continued)</u>			
Highway crossing		lump sum	\$ 2,500
Reservoir		lump sum	35,000
Right of way		lump sum	<u>5,000</u> \$ 151,400
<u>Snor Canyon Extension</u>			
Excavation and backfill	9,000 lin.ft.	\$ 0.80	7,200
Furnish and install 10-inch diameter welded steel pipe	9,000 lin.ft.	2.65	23,900
Gate valves - 6-inch dia.	2 each	300.00	600
Line meter		lump sum	1,000
Blowoff valves	2 each	200.00	400
Air valves	2 each	300.00	600
Service outlets	3 each	150.00	400
Concrete structures	40 cu.yd.	65.00	2,600
Miscellaneous metal	1,000 lbs.	0.65	600
Road surfacing	2,000 lin.ft.	0.60	1,200
Fire hydrants	3 each	150.00	400
Pumping plant		lump sum	13,700
Right of way		lump sum	<u>2,500</u> 55,100
<u>Canada Larga Conduit</u>			
Excavation and backfill	29,200 lin.ft.	0.80	23,400
Furnish and install 6-inch diameter welded steel pipe	29,200 lin.ft.	1.80	52,600
Gate valves - 4-inch dia.	4 each	170.00	700
Line meter		lump sum	400
Blowoff valves	3 each	100.00	300
Air valves	4 each	200.00	800
Service outlets	5 each	150.00	800
Concrete structures	50 cu.yd.	65.00	3,300
Miscellaneous metal	1,000 lbs.	0.65	600
Road surfacing	10,000 lin.ft.	0.55	5,500
Fire hydrants	6 each	150.00	900
Highway crossing		lump sum	1,000
Pumping plant		lump sum	8,500
Right of way		lump sum	<u>2,500</u> 101,300
<u>Concon Conduit</u>			
Excavation and backfill	99,000 lin.ft.	0.75	74,200
Furnish and install welded steel pipe			
10-inch diameter	79,000 lin.ft.	2.75	217,300
8-inch diameter	20,000 lin.ft.	2.25	45,000
Gate valves - 6-inch dia.	6 each	300.00	1,800

ESTIMATED COST OF DISTRIBUTION SYSTEM  
FROM CASITAS RESERVOIR  
(Continued)

Item	Quantity	Unit	price	Cost
CAPITAL COSTS				
<u>Rincon Conduit (Continued)</u>				
Line meter		lump sum	\$	1,000
Blowoff valves	10 each	\$ 200.00		2,000
Air valves	10 each	300.00		3,000
Service outlets	10 each	150.00		1,500
Concrete structures	80 cu.yd.	65.00		5,200
Miscellaneous metal	5,000 lbs.	0.65		3,200
Road surfacing	20,000 lin.ft.	0.60		12,000
Fire hydrants	10 each	150.00		1,500
Reservoir		lump sum		35,000
Pumping plant		lump sum		30,900
Right of way		lump sum		5,000
				<u>\$ 438,600</u>
<u>Conduit from Matilija Line to Proposed Reservoir</u>				
Excavation and backfill	5,000 lin.ft.	1.00		5,000
Furnish and install 14-inch diameter concrete cylinder pipe	5,000 lin.ft.	5.45		27,200
Gate valves - 12-inch dia.	2 each	450.00		900
Blowoff valves	2 each	200.00		400
Air valves	3 each	300.00		900
Service outlets	3 each	150.00		400
Concrete structures	40 cu.yd.	65.00		2,600
Miscellaneous metal	1,000 lbs.	0.65		600
Road surfacing	4,000 lin.ft.	0.60		2,400
Fire hydrants	4 each	150.00		600
Reservoir		lump sum		35,000
Right of way		lump sum		5,000
				<u>81,000</u>
Subtotal				\$2,316,700
Administration and engineering, 10%				\$ 231,700
Contingencies, 15%				347,500
Interest during construction				<u>57,900</u>
TOTAL				<u>\$2,953,800</u>
ANNUAL COSTS				
Interest, 4%			\$	118,200
Amortization, 40-year sinking fund at 4%				31,200
Replacement, 30-year sinking fund at 3.5%				9,700
Operation and maintenance				14,500
Electrical energy				<u>78,400</u>
TOTAL			\$	<u>252,000</u>

# ESTIMATED COST OF CASITAS - OXNARD PLAIN DIVERSION

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 25 second-feet      Length of conduit: 96,300 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	115,000 cu.yd	\$ 1.29	\$ 148,400
Backfill	94,800 cu.yd.	0.53	50,200
Pipe, reinforced concrete cylinder, furnish and install,			
30-inch diameter	49,000 lin.ft.	10.10	494,900
27-inch diameter	47,300 lin.ft.	8.93	422,400
Fittings		lump sum	41,800
Valves			
Air release, 3-inch dia.	6 each	300.00	1,800
Blowoff, 5-inch dia.	6 each	1,000.00	6,000
Gate, 24-inch dia. .	3 each	1,300.00	3,900
Venturi meter	1 each	5,000.00	5,000
River crossings		lump sum	85,000
Road resurfacing and crossings		lump sum	21,000
Right of way		lump sum	<u>29,800</u>
Subtotal			\$1,310,200
Administration and engineering, 10%			\$ 131,000
Contingencies, 15%			196,500
Interest during construction			<u>32,800</u>
TOTAL			\$1,670,500

## ANNUAL COSTS

Interest, 4%	\$66,800
Amortization, 20-year sinking fund at 4%	56,100
Operation and Maintenance	<u>4,200</u>
TOTAL	\$127,100



ESTIMATED COST OF SANTA CLARA RIVER CONDUIT  
DEVIL CANYON DAM TO SESPE CREEK

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 65 second-feet

Length of conduit: 90,200 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	142,000 cu.yd.	\$ 0.90	\$ 127,800
Backfill	114,800 cu.yd.	0.45	51,700
Pipe, reinforced concrete, furnish and install			
42-inch diameter	26,600 lin.ft.	16.19	430,700
36-inch diameter	63,600 lin.ft.	12.13	771,500
Fittings		lump sum	55,200
Valves			
Air release, 4-inch diameter	7 each	400.00	2,800
Blowoff, 6-inch diameter	8 each	1,300.00	10,400
Gate, 36-inch diameter	2 each	3,600.00	7,200
Venturi meter	1 each	5,000.00	5,000
River crossings		lump sum	65,000
Road resurfacing		lump sum	35,000
Right of way		lump sum	16,000
Subtotal			\$1,578,300
Administration and engineering, 10%			\$ 157,800
Contingencies, 15%			236,700
Interest during construction			39,500
TOTAL			\$2,012,300
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 80,500
Amortization, 40-year sinking fund at 4%			21,200
Operation and maintenance			5,000
TOTAL			\$ 106,700

ESTIMATED COST OF SANTA CLARA RIVER CONDUIT  
SANTA FELICIA DAM TO SESPE CREEK

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 65 second-feet      Length of conduit: 77,100 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	129,200 cu.yd.	\$ 0.90	\$ 116,300
Backfill	103,700 cu.yd.	0.45	46,700
Pipe, reinforced concrete, furnish and install			
42-inch diameter	54,200 lin.ft.	16.02	868,300
36-inch diameter	22,900 lin.ft.	11.65	266,800
Fittings		lump sum	56,800
Valves			
Air release, 4-inch dia.	7 each	400.00	2,800
Blowoff, 6-inch dia.	8 each	1,300.00	10,400
Gate, 36-inch dia.	2 each	3,600.00	7,200
Centuri meter	1 each	5,000.00	5,000
River crossings		lump sum	65,000
Road resurfacing		lump sum	35,000
Right of way		lump sum	<u>16,000</u>
Subtotal			\$1,496,300
Administration and engineering, 10%			\$ 149,600
Contingencies, 15%			224,400
Interest during construction			<u>37,400</u>
<b>TOTAL</b>			<b>\$1,907,700</b>
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 76,300
Amortization, 40-year sinking fund at 4%			20,100
Operation and maintenance			<u>4,800</u>
<b>TOTAL</b>			<b>\$ 101,200</b>

ESTIMATED COST OF SANTA CLARA RIVER CONDUIT  
SESPE CREEK TO OXNARD RESERVOIR

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 120 second-feet      Length of conduit: 92,500 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	211,000 cu.yd.	\$ 0.90	\$ 189,900
Backfill	159,700 cu.yd.	0.45	71,900
Pipe, reinforced concrete, furnish and install			
54-inch diameter	67,500 lin.ft.	20.10	1,356,800
48-inch diameter	15,000 lin.ft.	16.95	254,300
42-inch diameter	10,000 lin.ft.	14.25	142,500
Fittings		lump sum	81,700
Valves			
Air release, 4-inch dia.	4 each	400.00	1,600
Blowoff, 8-inch dia.	3 each	1,600.00	4,800
Gate, 48-inch dia.	3 each	8,700.00	26,100
Venturi meter	1 each	10,000.00	10,000
River crossings		lump sum	120,000
Road resurfacing		lump sum	10,000
Right of way		lump sum	<u>10,600</u>
Subtotal			\$2,280,200
Administration and engineering, 10%			\$ 228,000
Contingencies, 15%			342,000
Interest during construction			<u>57,000</u>
TOTAL			\$2,907,200
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 116,300
Amortization, 40-year sinking fund at 4%			30,600
Operation and maintenance			<u>7,300</u>
TOTAL			\$ 154,200



ESTIMATED COST OF SANTA CLARA RIVER CONDUIT  
SESPE FEEDER

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 55 second-feet      Length of conduit: 28,800 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Diversion works			
Excavation	9,770 cu.yd.	\$ 4.00	\$ 39,100
Concrete			
Weir and cutoff	3,620 cu.yd.	35.00	126,700
Walls	490 cu.yd.	50.00	24,500
Reinforcing steel	109,900 lbs.	0.15	16,500
Trashrack steel	16,700 lbs.	0.20	3,300
Outlet gates		lump sum	4,200
Sand trap		lump sum	9,800
			<u>\$ 224,100</u>
Pipe line			
Excavation	43,200 cu.yd.	0.95	41,000
Backfill	35,140 cu.yd.	0.45	15,800
Pipe, reinforced concrete, furnish and install, 36-inch dia.	28,800 lin.ft.	11.65	335,500
Fittings		lump sum	16,800
Valves, furnish and install			
Air release, 4-inch dia.	2 each	400.00	800
Blowoff, 8-inch dia.	2 each	1,500.00	3,000
Gate, 30-inch dia.	2 each	3,000.00	6,000
Meter and junction		lump sum	7,500
Road and railroad crossing		lump sum	3,000
Right of way		lump sum	8,500
			<u>437,900</u>
Subtotal			\$662,000
Administration and engineering, 10%			\$ 66,200
Contingencies, 15%			99,300
Interest during construction			<u>16,500</u>
TOTAL			<u>\$844,000</u>
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 33,800
Amortization, 40-year sinking fund at 4%			8,900
Operation and maintenance			<u>4,200</u>
TOTAL			<u>\$ 46,900</u>

# ESTIMATED COST OF OXNARD PLAIN-PLEASANT VALLEY DISTRIBUTION SYSTEM

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 120 second-feet      Length of conduit: 174,500 lineal feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Excavation	219,000 cu.yd.	\$ 0.90	\$ 197,100
Backfill	178,400 cu.yd.	0.45	80,300
Pipe, reinforced concrete, furnish and install	174,500 lin.ft.	9.49	1,656,000
Fittings		lump sum	82,800
Valves		lump sum	35,700
Line meters	3 each	4,000.00	12,000
Service outlets	191 each	150.00	28,700
Road and stream crossings		lump sum	5,000
Road resurfacing		lump sum	10,000
Regulating reservoirs		lump sum	250,000
Right of way		lump sum	<u>25,000</u>
Subtotal			\$2,382,600
Administration and engineering, 10%			\$ 238,300
Contingencies, 15%			357,400
Interest during construction			<u>59,400</u>
TOTAL			\$3,037,700

## ANNUAL COSTS

Interest, 4%	\$ 121,500
Amortization, 40-year sinking fund at 4%	32,000
Operation and maintenance	<u>15,200</u>
TOTAL	\$ 168,700

ESTIMATED COST OF OXNARD-PORT HUENEME  
CONVEYANCE AND PUMPING SYSTEM

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 40 second-feet      Length of conduit: 50,700 lineal feet

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
Pipe line				
Excavation	79,400 cu.yd.	\$	0.95	\$ 75,400
Backfill	65,900 cu.yd.		0.45	29,700
Pipe--furnish and install, reinforced concrete cylinder				
42-inch dia.	18,550 lin.ft.		14.25	264,300
36-inch dia.	4,250 lin.ft.		11.65	49,500
30-inch dia.	15,600 lin.ft.		9.30	145,100
24-inch dia.	12,300 lin.ft.		7.15	87,900
Fittings (elbows, re- ducers, enlargers, etc.)			lump sum	15,400
Valves--furnish and install				
Gate 36-inch dia.	1 each		1,800.00	1,800
Gate 30-inch dia.	3 each		1,200.00	3,600
Gate 24-inch dia.	1 each		800.00	800
Air release	3 each		400.00	1,200
Blowoff	3 each		500.00	1,500
Line meters	2 each		2,900.00	5,800
Road surfacing	9,500 lin.ft.		0.80	7,600
Railroad crossings	4 each		200.00	800
Right of way			lump sum	<u>10,000</u> \$ 700,400
Pumping system				
Well, gravel packed, drilled and cased, 18-inch dia.	16 each		3,750.00	60,000
Pump and motor installed	16 each		4,330.00	69,300
Pipe--furnish and install reinforced concrete cylinder				
42-inch dia.	1,500 lin.ft.		14.25	21,400
30-inch dia.	2,880 lin.ft.		9.30	26,800
18-inch dia.	3,220 lin.ft.		5.25	16,900
Valves--furnish and install				
Gate 18-inch dia.	7 each		600.00	4,200
Check 18-inch dia.	16 each		300.00	4,800
Land acquisition	40 acres		3,000.00	120,000
Fencing	9,600 lin.ft.		1.00	<u>9,600</u> <u>333,000</u>
Subtotal				\$1,033,400



ESTIMATED COST OF OXNARD-PORT HUENEME  
CONVEYANCE AND PUMPING SYSTEM  
(Continued)

Item	:	Quantity	:	Unit price	:	Cost
CAPITAL COSTS						
Administration and engineering, 10%						\$ 103,300
Contingencies, 15%						155,000
Interest during construction						<u>25,800</u>
TOTAL						\$1,317,500
ANNUAL COSTS						
Interest, 4%						\$ 52,700
Amortization, 40-year sinking fund at 4%						13,900
Replacement, 30-year sinking fund at 3.5%						1,300
Electrical energy						20,400
Operation and maintenance						<u>6,000</u>
TOTAL						\$ 94,300

# ESTIMATED COST OF PIRU-LAS POSAS DIVERSION CONDUIT

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 80 second-feet      Length of conduit: 67,500 lineal feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Excavation	167,840 cu.yd.	\$ 0.95	\$ 159,400
Backfill	123,820 cu.yd.	0.45	55,700
Pipe, lock joint concrete cylinder, furnish and install			
60-inch diameter	54,800 lin.ft.	39.53	2,166,200
54-inch diameter	12,700 lin.ft.	32.17	408,600
Valves			
Air release, 4-inch dia.	9 each	490.00	4,400
Blowoff, 8-inch dia.	9 each	1,650.00	14,900
Gate, 42-inch dia.	4 each	7,200.00	28,800
Fittings		lump sum	128,700
Line meters		lump sum	15,000
Structural concrete	220 cu.yd.	90.00	19,800
Miscellaneous metal	14,600 lbs.	0.55	8,000
Road resurfacing	25,000 lin.ft.	1.55	38,800
River crossings	700 lin.ft.	40.65	28,500
Happy Camp Canyon Tunnel	13,500 lin.ft.	165.00	2,227,500
Right of way		lump sum	<u>50,000</u>
Subtotal			\$5,354,300
Administration and engineering, 10%			\$ 535,400
Contingencies, 15%			803,100
Interest during construction			<u>267,700</u>
TOTAL			\$6,960,500

## ANNUAL COSTS

Interest, 4%	\$ 278,400
Amortization, 40-year sinking fund at 4%	73,200
Operation and maintenance	<u>17,400</u>
TOTAL	\$ 369,000

ESTIMATED COST OF SPREADING WORKS  
IN EAST LAS POSAS, AND SIMI BASINS

(Based on prices prevailing in spring of 1953)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<u>Happy Camp Spreading Works - Capacity 50 second-feet</u>			
Levees	89,220 cu.yd.	0.35	\$ 31,200
Strip checking grounds	50 acres	\$300.00	15,000
Riprap	1,200 cu.yd.	4.00	4,800
Feeder system to basins	2,600 lin.ft.	7.60	19,800
Stilling wells	3 each	700.00	2,100
Corrugated metal culverts, in place, including end sections, and toe- plates	15 each	240.00	3,600
Right of Way	50 acres	500.00	25,000
			\$ 101,500
<u>Happy Camp - Simi Lateral - Capacity 30 second-feet</u>			
Excavation	96,000 cu.yd.	0.95	91,200
Backfill	67,200 cu.yd.	0.45	30,200
Pipe--furnish and install 42-inch diameter concrete	48,000 lin.ft.	23.77	1,141,000
Valves		lump sum	7,400
			1,269,800
<u>Dry Canyon Spreading Works - Capacity 30 second-feet</u>			
Levees	121,200 cu.yd.	0.35	42,400
Strip checking ground	70 acres	300.00	21,000
Stilling well	1 each	700.00	700
Corrugated metal culverts, in place, including end sections, and toe- plates	18 each	240.00	4,300
Right of Way	70 acres	2,000.00	140,000
			208,400
Subtotal			\$1,579,700
Administration and engineering, 10%			\$ 158,000
Contingencies, 15%			237,000
Interest during construction			39,500
TOTAL			\$2,014,200
<b>ANNUAL COSTS</b>			
Interest, 4%			\$ 80,600
Amortization, 40-year sinking fund at 4%			21,200
Operation and maintenance			5,000
TOTAL			\$ 106,800



# ESTIMATED COST OF FILLMORE WELL FIELD

(Based on prices prevailing in spring of 1953)

Capacity of pumps: 55 second-feet  
 Gross seasonal pumpage: 22,000 acre-feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Well, gravel packed, drilled and cased, 18-inch diameter	18 each	\$3,080.00	\$ 55,400
Pump, motor and equipment, installed	18 each	4,330.00	77,900
Pipe, welded steel 18-inch diameter	3,600 lin.ft.	5.25	18,900
30-inch diameter	3,800 lin.ft.	10.10	38,400
Valves		lump sum	5,000
Fence	7,200 lin.ft.	1.00	7,200
Regulating reservoir		lump sum	20,000
Right of way	30 acres	1,500.00	<u>45,000</u>
Subtotal			\$267,800
Administration and engineering, 10%			\$ 26,800
Contingencies, 15%			<u>40,200</u>
Interest during construction			<u>3,300</u>
TOTAL			\$338,100

## ANNUAL COSTS

Interest, 4%	\$ 13,500
Amortization, 40-year sinking fund at 4%	3,600
Replacement, 30-year sinking fund at 3.5%	2,600
Electric energy	30,800
Operation and maintenance	<u>5,000</u>
TOTAL	\$ 55,500

ESTIMATED COST OF VENTURA COUNTY AQUEDUCT  
TO CONNECT WITH FACILITIES OF METROPOLITAN WATER DISTRICT  
OF SOUTHERN CALIFORNIA

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 25 second-feet      Length of conduit: 438,800 lineal feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Excavation	625,100 cu.yd.	\$ 1.70	\$ 1,062,700
Backfill	516,500 cu.yd.	0.76	392,500
Pipe, lock joint concrete cylinder furnish and install, 36-inch diameter	414,800 lin.ft.	17.30	7,176,000
24-inch diameter	5,000 lin.ft.	8.50	42,500
18-inch diameter	3,800 lin.ft.	6.50	24,700
Valves-furnish and install			
Air release - 3-inch diameter	49 each	325.00	15,900
Blowoff - 6-inch diameter	46 each	1,250.00	57,500
Gate	6 each	2,200.00	13,200
Venturi meter and equipment	2 each	18,000.00	36,000
Fittings (Elbows, reducers, enlargers, manholes, passholes, etc.)		lump sum	334,900
Road surfacing			
Temporary	16,600 tons	4.50	74,700
Permanent	23,700 tons	6.00	142,200
River crossings	3,450 lin.ft.	36.70	126,600
Railroad crossings	620 lin.ft.	38.00	23,600
Santa Susana tunnel	15,200 lin.ft.	165.00	2,508,000
Pumping plant and equipment	2 each	145,500.00	291,000
Right of way		lump sum	<u>76,000</u>
Subtotal			\$12,398,000
Administration and engineering, 10%			\$ 1,239,800
Contingencies, 15%			1,859,700
Interest during construction			<u>929,800</u>
TOTAL			\$16,427,300

ESTIMATED COST OF VENTURA COUNTY AQUEDUCT  
TO CONNECT WITH FACILITIES OF METROPOLITAN WATER DISTRICT  
OF SOUTHERN CALIFORNIA

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 50 second-feet. Length of conduit: 438,800 lineal feet.

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	883,600 cu.yd.	\$ 1.70	\$ 1,502,100
Backfill	675,200 cu.yd.	0.76	513,200
Pipe, lock joint concrete cylinder, furnish and install,			
48-inch diameter	414,800 lin.ft.	32.65	13,543,200
28-inch diameter	5,000 lin.ft.	9.60	48,000
24-inch diameter	3,800 lin.ft.	8.50	32,300
Valves-furnish and install			
Air release - 4-inch diameter	49 each	360.00	17,600
Blowoff - 8-inch diameter	46 each	1,550.00	71,300
Gate	6 each	6,450.00	38,700
Venturi meter and equipment	2 each	18,000.00	36,000
Fittings (Elbows, reducers, enlargers, man-holes, passholes, etc.)		lump sum	645,300
Road surfacing			
Temporary	30,300 tons	4.50	136,400
Permanent	42,400 tons	6.00	254,400
River crossings	3,450 lin.ft.	39.90	137,700
Railroad crossings	620 lin.ft.	58.00	36,000
Santa Susana tunnel	15,200 lin.ft.	165.00	2,508,000
Pumping plant and equipment	2 each	244,900.00	489,800
Right of way		lump sum	<u>76,000</u>
Subtotal			\$20,086,000
Administration and engineering, 10%			\$ 2,008,600
Contingencies, 15%			3,012,900
Interest during construction			<u>1,506,400</u>
TOTAL			\$26,613,900



ESTIMATED COST OF VENTURA COUNTY AQUEDUCT  
TO CONNECT WITH FACILITIES OF METROPOLITAN WATER DISTRICT  
OF SOUTHERN CALIFORNIA

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 75 second-feet      Length of conduit: 438,800 lineal feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Excavation	1,008,900 cu.yd.	\$ 1.70	\$ 1,715,100
Backfill	763,000 cu.yd.	0.76	579,900
Pipe, lock joint concrete cylinder, furnish and install, 54-inch diameter	414,800 lin.ft.	38.90	16,135,700
30-inch diameter	5,000 lin.ft.	10.10	50,500
28-inch diameter	3,800 lin.ft.	9.60	36,500
Valves-furnish and install			
Air release - 5-inch diameter	49 each	425.00	20,800
Blowoff - 10-inch diameter	46 each	1,650.00	75,900
Gate	6 each	6,450.00	38,700
Venturi meter and equipment	2 each	20,000.00	40,000
Fittings (elbows, reducers, enlargers, man-holes, passholes, etc.)		lump sum	771,300
Road surfacing			
Temporary	30,100 ton	4.50	135,400
Permanent	48,500 ton	6.00	291,000
River crossings	3,450 lin.ft.	43.47	150,000
Railroad crossings	620 lin.ft.	67.00	41,500
Santa Susana tunnel	15,200 lin.ft.	165.00	2,508,000
Pumping plant and equipment	2 each	331,900.00	663,800
Right of way		lump sum	<u>76,000</u>
Subtotal			\$23,330,100
Administration and engineering, 10%			\$ 2,333,000
Contingencies, 15%			3,499,500
Interest during construction			<u>1,749,800</u>
TOTAL			\$30,912,400

ESTIMATED COST OF VENTURA COUNTY AQUEDUCT  
TO CONNECT WITH FACILITIES OF METROPOLITAN WATER DISTRICT  
OF SOUTHERN CALIFORNIA

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 100 second-feet      Length of conduit: 438,800 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	1,151,200 cu.yd.	\$ 1.70	\$ 1,957,000
Backfill	851,000 cu.yd.	0.76	646,800
Pipe, lock joint concrete cylinder, furnish and install,			
60-inch diameter	414,800 lin.ft.	45.60	18,914,900
36-inch diameter	5,000 lin.ft.	13.00	65,000
30-inch diameter	3,800 lin.ft.	10.10	38,400
Valves-furnish and install			
Air release - 5-inch diameter	49 each	425.00	20,800
Blowoff - 10-inch diameter	46 each	1,650.00	75,900
Gate	6 each	14,680.00	88,100
Venturi meter and equipment	2 each	27,000.00	54,000
Fittings (elbows, reducers, enlargers, man-holes, passholes, etc.)		lump sum	906,800
Road surfacing			
Temporary	37,000 ton	4.50	166,500
Permanent	54,250 ton	6.00	325,500
River crossings	3,450 lin.ft.	47.11	162,500
Railroad crossings	620 lin.ft.	75.00	46,500
Santa Susana tunnel	15,200 lin.ft.	165.00	2,508,000
Pumping plant and equipment	2 each	411,600.00	823,200
Right of way		lump sum	76,000
Subtotal			\$26,875,900
Administration and engineering, 10%			\$ 2,687,600
Contingencies, 15%			4,031,400
Interest during construction			2,015,700
<b>TOTAL</b>			<b>\$35,610,600</b>

ESTIMATED COST OF VENTURA COUNTY AQUEDUCT TO CONNECT  
WITH FACILITIES OF METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

(Based on prices prevailing in spring of 1953)

Capacity of conduit: 150 second-feet      Length of conduit: 438,800 lineal feet

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
Excavation	1,464,300 cu.yd.	\$ 1.70	\$ 2,489,300
Backfill	1,035,000 cu.yd.	0.76	786,600
Pipe, lock joint concrete cylinder, furnish and install			
72-inch diameter	414,800 lin.ft.	60.40	25,053,900
42-inch diameter	5,000 lin.ft.	21.10	105,500
36-inch diameter	3,800 lin.ft.	13.00	49,400
Valves-furnish and install			
Air release - 6-inch dia.	49 each	490.00	24,000
Blowoff - 12-inch dia.	46 each	1,750.00	80,500
Gate	6 each	14,680.00	88,100
Venturi meter and equipment	2 each	27,000.00	54,000
Fittings (elbows, reducers, enlargers, manholes, pass-holes, etc.)		lump sum	1,200,400
Road surfacing			
Temporary	44,300 tons	4.50	199,400
Permanent	66,400 tons	6.00	398,400
River crossings	3,450 lin.ft.	50.70	174,900
Railroad crossings	620 lin.ft.	90.00	55,800
Santa Susana tunnel	15,200 lin.ft.	165.00	2,508,000
Pumping plant and equipment	2 each	501,650.00	1,003,300
Right of way		lump sum	76,000
Subtotal			\$34,347,500
Administration and engineering, 10%			\$ 3,434,800
Contingencies, 15%			5,152,100
Interest during construction			<u>3,434,800</u>
<b>TOTAL</b>			<b>\$46,369,200</b>



# ESTIMATED COST OF OAK CANYON LATERAL

(Based on prices prevailing in the spring of 1953)

Capacity of conduit: 40 second-feet

Length of conduit:  
4,010 lineal feet

Item	Quantity	Unit price	Cost
CAPITAL COSTS			
Excavation	7,100 cu.yd.	\$ 0.90	\$ 6,400
Backfill	5,700 cu.yd.	0.45	2,600
Pipe, lock joint concrete cylinder, furnish and install, 42-inch diameter	4,010 lin.ft.	22.30	89,400
Valves - furnish and install			
Air release, 4-inch diameter	2 each	350.00	700
Blowoff, 8-inch diameter	2 each	1,550.00	3,100
Gate, 36-inch diameter	1 each	6,500.00	6,500
Fittings (elbows, reducers, enlargers, etc.)		lump sum	9,200
Right of way		lump sum	4,000
Pumping plant and equipment		lump sum	<u>38,500</u>
Subtotal			\$160,400
Administration and engineering, 10%			\$ 16,000
Contingencies, 15%			24,100
Interest during construction; none			<u>---</u>
TOTAL			\$200,500

ESTIMATED COST OF OAK CANYON DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 7,500 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 1,110 feet  
Elevation of crest of spillway: 1,100 feet  
Height of dam to spillway crest,  
above stream bed: 170 feet

Capacity of reservoir to crest  
of spillway: 7,500 acre-feet  
Capacity of spillway with 5-foot  
freeboard: 2,000 second-feet

Item	Quantity	Unit price	Cost	
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum	\$ 10,000	
Diversion of stream and dewatering of foundation		lump sum	1,000	
Stripping topsoil	25,000 cu.yd.	\$ 0.60	15,000	
Foundation excavation				
Abutment	22,000 cu.yd.	1.50	33,000	
Channel	91,000 cu.yd.	0.60	54,600	
Embankment				
Impervious	586,400 cu.yd.	0.65	381,200	
Random	1,000,300 cu.yd.	0.55	550,200	
Rock riprap	39,400 cu.yd.	4.00	157,600	
Drilling grout holes	6,400 lin.ft.	3.00	19,200	
Pressure grouting	4,200 cu.ft.	4.00	16,800	\$1,238,600
<b>Spillway</b>				
Excavation	900 cu.yd.	1.50	1,400	
Concrete				
Weir and cutoff	230 cu.yd.	35.00	8,000	
Floor	420 cu.yd.	30.00	12,600	
Walls	420 cu.yd.	40.00	16,800	
Reinforcing steel	75,600 lbs.	0.15	11,300	50,100
<b>Outlet Works</b>				
Tower concrete	580 cu.yd.	80.00	46,400	
Concrete encasement	470 cu.yd.	40.00	18,800	
Steel pipe, 48-inch dia.	1,020 lin.ft.	25.00	25,500	
Tower inlet valve, 30- inch dia.	4 each	3,000.00	12,000	
Needle valve, 42-inch dia.	1 each	12,000.00	12,000	
Miscellaneous metal work	17,500 lbs.	0.40	7,000	121,700
<b>Reservoir</b>				
Land acquisition		lump sum	48,000	
Clearing	160 acres	10.00	1,600	49,600
Subtotal				\$1,460,000
Administration and engineering, 10%				\$ 146,000
Contingencies, 15%				219,000
Interest during construction				36,000
<b>TOTAL</b>				<b>\$1,861,000</b>

ESTIMATED COST OF CONEJO DAM AND RESERVOIR  
WITH STORAGE CAPACITY OF 20,000 ACRE-FEET

(Based on prices prevailing in spring of 1953)

Elevation of crest of dam: 375 feet	Capacity of reservoir to crest of spillway: 20,000 acre-feet
Elevation of crest of spillway: 360 feet	Capacity of spillway with 5-foot freeboard: 6,000 second-feet
Height of dam to spillway crest, above stream bed: 130 feet	

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<b>Dam</b>				
Exploration		lump sum		\$ 20,000
Diversion of stream and dewatering of foundation		lump sum		10,000
Stripping topsoil	45,000 cu.yd.	\$	0.60	27,000
Foundation excavation				
Abutment	97,000 cu.yd.		1.50	145,500
Channel	400,400 cu.yd.		0.60	240,200
Embankment				
Impervious	826,190 cu.yd.		0.70	578,300
Random	828,820 cu.yd.		0.60	497,300
Rock riprap	28,800 cu.yd.		4.00	115,200
Drilling grout holes	11,900 lin.ft.		3.00	35,700
Pressure grouting	7,900 cu.ft.		4.00	<u>31,600</u>
				\$1,700,800
<b>Spillway</b>				
Excavation	120,000 cu.yd.		2.00	240,000
Concrete				
Weir and cutoff	230 cu.yd.		35.00	8,100
Floor	700 cu.yd.		30.00	21,000
Walls	1,000 cu.yd.		40.00	40,000
Reinforcing steel	153,000 lbs.		0.15	<u>23,000</u>
				332,100
<b>Outlet Works</b>				
Tower concrete	500 cu.yd.		80.00	40,000
Concrete encasement	600 cu.yd.		40.00	24,000
Steel pipe 72-inch dia.	800 lin.ft.		45.00	36,000
Tower inlet valve 36-inch dia.	4 each		5,000.00	20,000
Needle valve 60-inch dia.	1 each		27,500.00	27,500
Miscellaneous metal work	35,000 lbs.		0.40	<u>14,000</u>
				161,500
<b>Reservoir</b>				
Land acquisition		lump sum		70,000
Clearing	350 acres		50.00	<u>17,500</u>
				87,500
Subtotal				\$2,281,900
Administration and engineering, 10%				\$ 228,200
Contingencies, 15%				342,300
Interest during construction				<u>114,000</u>
TOTAL				\$2,966,400



ESTIMATED COSTS OF DISTRIBUTION SYSTEM FOR COLORADO RIVER WATER  
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT

(Based on prices prevailing in spring of 1953)

Item	Quantity	Unit price	Cost
<b>CAPITAL COSTS</b>			
<u>Simi-Las Posas Feeder</u> - - Capacity: 65 second-feet			
Excavation	26,300 cu.yd.	\$ 0.90	\$ 23,700
Backfill	20,000 cu.yd.	0.45	9,000
Pipe, furnish and install reinforced concrete	12,500 lin.ft.	24.50	306,300
Fittings		lump sum	14,500
Valves		lump sum	11,200
Line meters		lump sum	6,000
Road resurfacing	800 tons	7.50	6,000
Right of way		lump sum	4,000
			\$ 380,700
<u>Simi Lateral</u> - - Capacity: 15 second-feet			
Excavation	33,800 cu.yd.	0.90	30,400
Backfill	29,200 cu.yd.	0.45	13,100
Pipe, furnish and install reinforced concrete	27,000 lin.ft.	9.69	261,600
Fittings		lump sum	11,900
Valves		lump sum	2,200
Line meters		lump sum	2,000
Road crossings		lump sum	2,000
Road resurfacing	430 tons	7.50	3,200
Regulating reservoir		lump sum	38,300
			364,700
<u>Las Posas Lateral</u> - - Capacity: 50 second-feet			
Excavation	134,100 cu.yd.	0.90	120,700
Backfill	110,500 cu.yd.	0.45	49,700
Pipe, furnish and install reinforced concrete	97,200 lin.ft.	16.29	1,583,300
Fittings		lump sum	147,200
Valves		lump sum	47,900
Line meters		lump sum	5,000
Road crossing		lump sum	22,000
Road resurfacing	2,100 tons	7.50	15,700
Regulating reservoir		lump sum	80,000
Right of way		lump sum	24,000
			2,095,500
<u>Conejo Feeder</u> - - Capacity: 30 second-feet			
Excavation	25,100 cu.yd.	0.90	22,600
Backfill	20,900 cu.yd.	0.45	9,400
Pipe, furnish and install reinforced concrete	17,200 lin.ft.	12.48	214,600
Fittings		lump sum	13,000
Valves		lump sum	13,400
Line meters		lump sum	4,000
Road crossings		lump sum	1,000
Road resurfacing	370 tons	7.50	2,800
Regulating reservoir		lump sum	70,000
Right of way		lump sum	10,300
			361,100

ESTIMATED COSTS OF DISTRIBUTION SYSTEM FOR COLORADO RIVER WATER  
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT  
(Continued)

Item	Quantity	Unit price	Cost
<b>APITAL COSTS</b>			
<u>Thousand Oaks Lateral</u> - - Capacity: 10 second-feet			
Excavation	18,100 cu.yd.	\$ 0.90	\$ 16,300
Backfill	16,200 cu.yd.	0.45	7,300
Pipe, furnish and install reinforced concrete	19,400 lin.ft.	7.84	152,100
Fittings		lump sum	9,600
Valves		lump sum	2,500
Line meters		lump sum	2,000
Road crossings		lump sum	1,500
Road resurfacing	80 tons	7.50	600
Regulating reservoir		lump sum	38,300
Right of way		lump sum	14,900
			\$ 245,100
<u>Newbury Park Lateral</u> - - Capacity: 15 second-feet			
Excavation	24,700 cu.yd.	0.90	22,200
Backfill	21,900 cu.yd.	0.45	9,900
Pipe, furnish and install reinforced concrete	31,900 lin.ft.	6.32	201,600
Fittings		lump sum	12,800
Valves		lump sum	4,400
Line meters		lump sum	2,000
Road crossings		lump sum	700
Road resurfacing	540 tons	7.50	4,100
Regulating reservoir		lump sum	44,000
Right of way		lump sum	15,700
			317,400
Subtotal			\$3,764,500
Administration and engineering, 10%			\$ 376,400
Contingencies, 15%			564,700
Interest during construction			94,100
TOTAL			\$4,799,700
<b>ANNUAL COSTS</b>			
Interest, 4%			\$192,000
Mortization, 40-year sinking fund at 4%			50,500
Operation and maintenance			14,400
TOTAL			\$256,900

ESTIMATED COST OF CONDUIT TO DELIVER  
COLORADO RIVER WATER FROM CONEJO RESERVOIR  
TO OXNARD REGULATING RESERVOIR AND THE CITY OF VENTURA

(Based on prices prevailing in spring of 1953)

Item	Quantity	Unit	price	Cost
<b>CAPITAL COSTS</b>				
<u>Conejo Reservoir to Oxnard Regulating Reservoir - capacity 150 second-feet</u>				
Excavation	227,200 cu.yd.	\$	0.90	\$ 204,500
Backfill	164,900 cu.yd.		0.45	74,200
Pipe, furnish and install 66-inch dia. lock joint concrete cylinder	73,200 lin.ft.		44.70	3,272,000
Fittings			lump sum	163,600
Valves			lump sum	13,000
Line meter	1 each		5,000.00	5,000
River crossing			lump sum	10,000
Road resurfacing	12,000 tons		6.00	72,000
Right of way			lump sum	5,000
				<u>\$3,819,300</u>
<u>Oxnard Reservoir to City of Ventura - capacity 25 second-feet</u>				
Excavation	55,500 cu.yd.		1.05	58,300
Backfill	46,300 cu.yd.		0.55	25,500
Pipe, furnish and install 36-inch dia. lock joint concrete cylinder	37,000 lin.ft.		13.00	481,000
Fittings			lump sum	24,100
Valves			lump sum	8,100
Line meter	1 each		2,000.00	2,000
River crossing	2,200 lin.ft.		35.00	77,000
Road resurfacing	8,000 tons		6.00	48,000
Terminal reservoir			lump sum	44,000
Right of way			lump sum	15,000
				<u>783,000</u>
Subtotal				\$4,602,300
Administration and engineering, 10%				\$ 460,200
Contingencies, 15%				690,300
Interest during construction				<u>115,100</u>
TOTAL				<u>\$5,867,900</u>
<b>ANNUAL COSTS</b>				
Interest, 4%				\$ 234,700
Amortization, 40-year sinking fund at 4%				61,700
Operation and maintenance				<u>14,500</u>
TOTAL				<u>\$ 310,900</u>



APPENDIX D

SOME ORGANIZATIONAL AND FINANCIAL ASPECTS INVOLVED  
IN IMPLEMENTING WATER PLANS IN VENTURA COUNTY

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### SOME ORGANIZATIONAL AND FINANCIAL ASPECTS INVOLVED IN IMPLEMENTING WATER PLANS IN VENTURA COUNTY

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SOME ORGANIZATIONAL AND FINANCIAL ASPECTS INVOLVED  
IN IMPLEMENTING WATER PLANS IN VENTURA COUNTY

INTRODUCTION

Future economic expansion in Ventura County is believed to be inextricably involved with the development of its water resources, together with the furnishing of supplemental supplies and the importation of water from outside the County. In a number of areas throughout the County, utilization of the local water supply is nearly complete, and in some areas the water supply as presently developed is used beyond its safe limits. In these latter instances, the security of investments made many years ago, as well as of those recently made, is becoming increasingly jeopardized. Possibilities for sound future economic growth within the County appear to be remote under present water supply conditions.

The physiography of Ventura County, and the location and type of mineral, agricultural, and other resources therein, present challenges to the people of the County with respect to planning for future economic growth, including planning to provide utility services for such growth. How the people respond to these challenges will determine the economic course of the future.

Because of the unique physiography, the climatic characteristics, and the concentrations of population which bear little relation with concentrations of assessed valuation of taxable property, the matter of initiating water resources development plans for Ventura County appears to require somewhat unusual approaches with respect to organizational and financial aspects. The objectives of this appendix report are: (1) a general review of the purposes and powers of existing organized public water districts in Ventura County; (2) discussion of the adequacy of existing water districts with regard to solution of the County's water problems; and (3) suggestion of a county-wide



type of water district which would plan, finance, construct, and operate water resources projects.

## EXISTING ORGANIZED PUBLIC WATER DISTRICTS

In California there are so many kinds of water districts that may be organized by local interests, each kind of which is designed to meet a special circumstance or need, that it behooves local interests to be certain that they either have, or organize, a type of district that best fits their overall needs. The Legislature has enacted more than 30 general and more than 30 special water district acts for the primary purpose of assisting local interests to resolve their local water problems.

Investigation of Ventura County and its water problems indicates that there are several factors that should be considered in ascertaining what type of public water district is desirable, and whether the existing district are satisfactory to cope with the problems at hand. These factors include the following: the purposes and powers of the district, the basis of voting, the type of governing board, restrictions on and kinds of indebtedness that may be incurred, and the legally available sources of revenue that may be obtained and used to retire such indebtedness. These matters will be considered in describing the existing districts, and in suggesting what types of districts may be desirable for Ventura County.

### Ventura County Flood Control District

This district was organized in 1944, under the provisions of a special enabling act passed by the Legislature, known as the "Ventura County Flood Control Act". It is the only district that embraces the entire County. Its purposes and powers were appreciably broadened by passage of Assembly Bill No. 494 by the Legislature in 1953. Among other things, the District may

control flood and storm waters, store, spread and sink water, reclaim water, import water, sell water, and levy charges for the use of ground water in areas where the District spreads water. The District is divided into four zones to accomplish these objectives, and for bonding and assessment purposes.

The basis of voting is the qualified registered voter. Thus, tenant and landlord have equal voting power. The Ventura County Board of Supervisors constitutes the governing board of the District. General obligation bonds only may be issued and shall be a lien upon all, but only on the taxable property of the zone of issuance, not the entire District. Said bonds are declared by law to be legal investments and shall be paid from assessments levied within the zone, or out of any other fund of the zone. A two-thirds favorable vote by the electorate in the zone affected is necessary to approve a bond issue. No zone, nor the property therein, shall be liable for the bonded indebtedness of any other zone. Ad valorem taxes may be levied upon all taxable property in the District to pay district costs that are of common benefit to the whole District.

The Ventura County Flood Control District does not have specific powers to develop and sell hydroelectric power, issue general obligation bonds which would be a lien upon the entire District, and issue revenue bonds.

#### Water Conservation Districts

There are four water conservation districts in Ventura County, namely: San Antonio, Santa Clara, Simi Valley, and United. These districts have been formed under two general enabling acts.

The earliest known district of this type formed in the County is the Santa Clara Water Conservation District, which was organized in 1927 under the "Water Conservation Act of 1927". Its powers and purposes are somewhat limited in that there are no provisions with respect to the issuance and sale

of bonds, and its assessment powers are limited. However, within the foregoing severe financial restrictions, the District may acquire, store, and distribute surface water supplies for irrigation, seasonal storage or underground replenishment; construct, operate, and maintain works; sell water supplies for surface irrigation; and provide flood protection facilities. The basis of voting is one vote per acre or fraction thereof. There are only a few districts in the State organized under this particular act. The Santa Clara Water Conservation District held an election in 1953 to dissolve the district. However, the proposition failed to carry.

In 1929, an alternative law was enacted by the Legislature. In 1931 it was modified and is now known as the "Water Conservation Act of 1931". It is under these latter two acts that the remaining Ventura County water conservation districts were organized. The purposes and powers of districts organized under the 1931 act are somewhat broader in scope and generally more adequate than those organized under the 1927 act. Such districts may not generate and sell hydro-power but may, among other things, conserve and store water by almost any manner of means for any useful purpose, including the sinking in wells and spreading of water; install and operate wells, pumps, etc.; and sell, deliver, and otherwise dispose of water.

Members of the boards of directors are elected by the resident registered voters of the districts. General obligation bonds, approved by a two-thirds vote, may be issued. No revenue bonds are authorized. Ad valorem assessments may be levied on lands or real property, whichever is preferred. Improvement districts may be organized.

In addition to the foregoing powers, the Legislature of 1953 granted the United Water Conservation District special powers to own and operate hydro electric power facilities in conjunction with its water conservation projects, and to sell electrical energy at wholesale at the point of generation.



## County Water Districts

This type of district is one of the most popular in California, although there is only one in Ventura County - the Meiners Oaks County Water District.

The county water district has broad powers. It can, among other things, furnish water for any beneficial use, store and conserve water, generate and sell hydroelectric power, salvage water, sell or lease oil or mineral rights, and cooperate with other entities. The resident registered voter is eligible to vote, and the five-man board of directors is elected from the eligible electorate. Improvement districts may be created to finance projects that are not of benefit to the district as a whole. The district may issue general obligation and revenue bonds. A two-thirds favorable vote of the electorate is required for approval of all bond issues. Revenue may be obtained from sales or leases of facilities and services, including water. Assessments are based upon an ad valorem levy on all taxable property in the district. However, bond assessments may be levied only on those properties so benefited by the bond issue.

This type of district is often desirable when water facilities for both urban and rural uses are involved.

## County Waterworks Districts

There are seven districts of this type in Ventura County, as follows:

County Waterworks Districts No. 1 (Moorpark), No. 2 (Heuneme), No. 3 (Simi), No. 4 (Casitas Springs), No. 5 (Camarillo), No. 6 (Thousand Oaks), and No. 7 (Live Oaks Acres).

County waterworks districts organized under the enabling act have defined purposes and powers that are more circumscribed than those of a county water district or a water conservation district. Overlapping of boundaries of

certain other types of districts is prohibited. Resident registered voters may vote, and the county board of supervisors is the governing board of the district. The board may appoint directors from among the registered voters who are also owners of real property within the district.

General obligation and revenue bonds may be issued, subject to a majority approved vote by the electorate. Special zones or improvement districts may be formed to construct and finance facilities, or to fix special rates and charges. The district can obtain revenue from the sale of water, and from leases or sales of property. Ad valorem assessments may be levied upon all taxable property.

#### Municipal Water Districts

The Ventura River Municipal Water District, formed in 1952, is the only one of this type in Ventura County. Residents of the Calleguas Creek watershed area will soon vote on forming the Calleguas Municipal Water District.

This type of district has broad purposes and powers and may, among other things, acquire water works, water rights, store and distribute water, sell water to all public and private entities and to individuals, salvage water, and spread and purify water. However, it may not develop hydroelectric power potentialities, nor carry on flood control activities.

The area of the district may include both incorporated and unincorporated territory. Resident registered voters may vote. Members of the board of directors are elected by qualified voters in the district. Improvement districts may be formed for certain special purposes which do not equally affect the district as a whole. General obligation bonds only may be issued, subject to approval by a two-thirds vote, and are declared by law to be legal investments. Revenue may accrue from a number of sources. Ad valorem assessments may be levied upon all taxable property.

## Other Public and Private Water Agencies

In addition to the foregoing public water districts in Ventura County, there are four soil conservation districts, two of which lie wholly within the County, nine privately owned public water service utilities, and more than ninety mutual water companies.

Soil conservation districts exist for the principal purposes of control of runoff, prevention and control of soil erosion, improvement of farm irrigation, development of farm storage and distribution of water, and land drainage. Although the purposes of such districts are commendable, their limited financing capacity, together with the nature and characteristics of their projects, precludes further consideration of soil conservation districts for purposes of implementing the water development program outlined in this bulletin.

The privately owned public utility is operated for profit, and sells a service subject to the regulations of the State Public Utilities Commission. Because it must operate for profit purposes, and because venture capital flows to those areas and activities in which either the risks are less or the net returns are more than those accruing from financing water supply facilities, this type of public utility in recent years has not been able to resolve complex water problems. The number of privately owned water utilities is dwindling as public water districts are formed for the purpose of acquiring private properties and operating them. It is not a so-called community type of organization.

The mutual water company is a community organization which may be incorporated or unincorporated. It is a voluntary nonprofit enterprise, primarily engaged in supplying water to its stockholding members. Like the foregoing commercial utility, it has no power of taxation. The mutual water company is controlled by its members rather than by the qualified electors.



It is not required to serve water to nonmembers, and no one is compelled to join it. Only where water problems are not complex, water users are relatively few in number, and simplicity and ease of formation and operation are desired and possible, does this type of organization appear to be suitable.

#### ADEQUACY OF EXISTING WATER DISTRICTS AS REGARDS SOLUTION OF COUNTY WATER PROBLEMS

Existing institutional factors in Ventura County are deemed to be inadequate for the purpose of implementing a plan of comprehensive county-wide water development. The existing districts, with their present limited power, jurisdictional areas, and tax bases, are not equipped to finance, construct, or operate water resource development works of the magnitude required to solve the water problems of Ventura County. Neither are they adequate to facilitate the equitable distribution of necessary supplemental water to areas of need.

In spite of the number of public water districts that now exist in Ventura County, relatively little has been accomplished in the aggregate toward resolving the County's water problems. Annual sums disbursed by the County and special districts for water amount to only about one per cent of the aggregate sum disbursed for all activities. The Santa Clara Water Conservation District has been spreading runoff waters for a number of years, an activity recently taken over by the United Water Conservation District. Zones of the Ventura County Flood Control District has constructed and operates the Matilija Dam and Reservoir. The United Water Conservation District is undertaking a \$10,900,000 program on Piru Creek with the objective of resolving its water problems. However, these steps, though pointed in the right direction, are only a small beginning of what could and should be accomplished.

The Ventura River Municipal Water District appears to be the only district with sufficient present financial capacity to develop supplemental water supplies to fully satisfy present water supply deficiencies within the

district boundaries. In the case of this District, under the most feasible plan for development of the Ventura River watershed, a relatively large surplus of water over and above present requirements within the district boundaries would be developed. An immediate market for this surplus is available in the coastal plain of the Santa Clara River Valley outside the limits of the District. However, desirable interim use of this surplus supplemental water supply in the Oxnard Plain and Pleasant Valley Subunits would be facilitated if the export were under the jurisdiction of a district with broader powers and areal jurisdiction than the Ventura River Municipal Water District. Such interim export and sale of the surplus water could ease the financial burden of taxpayers and water users in said District.

Existing water districts do not appear to be either financially capable or equipped with sufficient legal powers to effect the indicated desirable diversion of surplus waters in Piru Creek for use in the water-deficient Calleguas-Conejo Hydrologic Unit. Under the plan recommended in this bulletin, sufficient water could be diverted and regulated for use in ground water storage in the Calleguas-Conejo Hydrologic Unit to alleviate present water shortages therein, and to provide for some future expansion. Such diversion appears to be the only immediate feasible source of supplemental water for this area.

Based upon the following observations: The generally increasing seriousness of the ground water overdraft in Ventura County; the difficulty that existing districts have experienced in implementing development plans; and the tendency of local interests to be divisive with respect to water resources development, a factor which is aggravated by the zonal type of organization of the Ventura County Flood Control District; and in realization of the fact that imported water will be needed to supplement local supplies; and that full development of the water resources of the several watersheds,

within the limits of engineering and economic feasibility, will enable transfer of surplus water from one watershed to another; it is believed that the day of independent, uncoordinated, piecemeal planning and implementation of water supply facilities is past, and that an adequate agency is needed now to accomplish what has not been accomplished to date.

SUGGESTED COUNTY-WIDE TYPE OF WATER DISTRICT  
TO CARRY OUT WATER DEVELOPMENT PLANS, AND  
POSSIBLE METHODS OF FINANCING SUCH PLANS

It is believed that implementation of comprehensive water plans for Ventura County, as set forth in this bulletin, requires the coexistence of a county-wide water district and a number of smaller supporting water districts hereinafter referred to as member units. There are presently about 20 county wide water districts in California, of which about one-third are flood control districts such as the one in Ventura County. Most of the remaining two-thirds are so-called flood control and water conservation districts. As water supply problems become increasingly complex and involved due to fluctuating precipitation and fast growing demands for water, it is believed that county-wide districts may well assume increasing importance in resolving future water problems of California. The county-wide water district concept is being adopted on a rapidly increasing scale as a natural extension of the local district type in coping with problems of increasing magnitude and number. In one county, the thinking has advanced on water matters to the point that the county government contributes \$100,000 annually to the county-wide water district, to be used to help defray water costs of several member districts which purchase water under long-term contracts from the larger district. In another county, the county-wide water district is proposing to sell irrigation water at below cost to one of its member units, with the loss in revenue estimated at \$150,000 to \$200,000 per year, to be recouped by means of levying a tax on all of the taxable property of the county.



Principal functions of the county-wide water district proposed for Ventura County, in addition to those already granted by the Ventura County Flood Control District Act as amended, would be facilitating the financing of projects, the construction and probable operation and maintenance of such projects, and the execution of water service contracts with member units. In order to carry out these purposes, it is recommended that additional authority would have to be granted to the district by the Legislature, such as permitting the county-wide district to issue bonds, the proceeds from the sale of which would be used for constructing water development projects, which would constitute a lien upon all of the taxable property in the entire County, even though the proceeds thereof might be used to benefit a smaller area. However, it is further recommended that the direct beneficiaries of the project, acting through some subordinate organization, would, concurrent with the issuance of the bonds, execute water service contracts with the county-wide district, with the rates for water being set at a price that over a period of years would pay for operation and maintenance costs, replacement costs, and bond service charges.

The foregoing discussion assumes that general obligation bonds would be issued. An alternative to this means of raising funds for construction would be the issuance of revenue bonds. The holder of such bonds would probably have first claim to all project revenues. In calling for bids for such bonds the district would probably require a minimum bid of par, with the interest rate or rates to be fixed by the bidder. In determining whether to bid at all or what interest rate to specify, groups or syndicates of investment bankers would take into consideration primarily the extent to which estimated net revenues were in excess of bond service requirements. Depending on the extent to which net revenues could be predicted with certainty, based on firm contracts or commitments for water service, they would be expected to equal at least 1.2 times bond service, with the requirements being probably

1.4 times bond service charges if such revenue estimates were less certain. However at the present time, the Ventura County Flood Control District cannot issue revenue bonds.

From the foregoing, it is believed that the particular local area using project water would not be required to raise large funds in advance, and would not necessarily need to hire a staff of qualified personnel to operate and maintain the project. Instead, the county-wide agency could perform such services. The county-wide agency would probably have less difficulty in raising funds through sale of bonds because the entire County's taxing power would support the bonds, and because of the contracts it would have with subordinate districts for the sale of water, a portion of the revenues from which would be used to pay off bond service charges. Thus, the county-wide district might be able to obtain more favorable interest rates and other more favorable bond issuance features than could the member units. Furthermore, the county-wide district could and should act as arbiter in disputes over water matters between member units. It should also determine that any surplus waters created by a project would be utilized in adjacent water-deficient areas within the scope of economic limitations.

Ventura County is in the upper quarter of counties in California with respect to assessed valuations. Such values have increased at an impressive rate over a period of several decades. For instance, in the fiscal year 1909-10 the total assessed valuation was \$22,189,000; in 1919-20, \$38,264,000; in 1929-30, \$106,620,000; in 1939-40, \$96,513,000; and in 1949-50, \$228,724,000. In the fiscal year 1953-54, the total amounted to \$300,966,000.

Inflation during the past dozen years accounts for a portion of the foregoing almost phenomenal recent increases in assessed valuations. However the principal increase may be attributed to growth in population and increase in output of goods and services in Ventura County. For instance, the population

of Ventura County increased from 18,347 in 1910 to 69,685 in 1940, and to 114,647 in 1950. The State Department of Finance estimates that as of July 1, 1953, the population was 133,100, almost double that of 1940. Petroleum production increased from 17,038,470 barrels in 1940, valued at \$18,525,000, to almost 34,000,000 barrels in 1950, valued at \$92,550,000. Gross farm income (F.O.B. value) increased from \$22,600,000 in 1940 to \$75,300,000 in 1952.

Total public bonded indebtedness in Ventura County as of June 30, 1953, was \$15,660,000, including school bonds of \$11,221,200, and flood control (Zone 1), county water district, and county waterworks districts bonds in the amount of \$3,083,000. In addition to this total, there were more than \$3,000,000 in bonds, including self-supporting bonds, issued by the municipalities of Ventura, Santa Paula, Oxnard Ojai, and Port Heuneme. Excluding the municipal issues, the ratio of about five per cent of outstanding bonded indebtedness to total assessed valuation is below the reported average for all counties of the State. However, unlike that for Ventura County, such ratios calculated for many other counties in the State are misleading inasmuch as they do not include, for example, irrigation district bonds.

It is recommended in this bulletin that a plan of water resources development in Ventura County be adopted, including construction of Casitas Dam and Reservoir with a storage capacity of 130,000 acre-feet, Devil Canyon Dam and Reservoir with a storage capacity of 150,000 acre-feet, a well field in Fillmore Basin, and certain distribution and conveyance facilities, at an estimated capital cost of about \$52,000,000. The over-all average annual cost of about 73,000 acre-feet of new water developed by the plan would be \$40 per acre-foot, with average annual unit costs varying from \$62 in the Ventura Hydrologic Unit to \$33 in the Santa Clara River Hydrologic Unit. The bulletin further recommends that, if financial capacity does not permit immediate



construction of all features of the plan, a staged development be undertaken whereby construction of those features relating to the proposed diversion to the Calleguas-Conejo Hydrologic Unit be postponed. The estimated capital cost of the initial works under such staged development would be about \$43,000,000.

Pursuant to the act creating the Ventura County Flood Control District, bonds (general obligation) issued by the District, which are issued for any zone thereof, shall be legal investments for all trust funds and for the funds of banks, insurance companies, and for other related types of funds. However, this arbitrary declaration of what constitutes a legal investment may not, on occasions, mean much to the prospective bidder for such bonds unless certain other criteria have been met.

One of the foregoing criteria may be whether the proposed issue meets the requirements of the State Financial Code regarding legal investment. Section 1356(g) of that Code states that:

"... the net direct debt of such public corporation or of such special district together with its net overlapping debt does not exceed 20 per cent of the assessed valuation of the taxable property within its boundaries . . .".

In some instances, public district bonds have been sold in which the foregoing 20 per cent limitation has been exceeded. However, under such conditions bond salability oftentimes is made more difficult inasmuch as the number of eligible buyers is reduced, and the interest rate must then be increased, or some other concession made, to enhance the salability.

A second possible criterion that may be requested by the prospective bond purchaser is that such bonds be certified by the California District Securities Commission as legal securities, pursuant to Section 20045 of the State Water Code, quoted hereafter:

"20045. Except as herein provided, no bond issue of any district shall be approved for certification which together with any other outstanding bonds and bonds authorized but not issued of the district exceeds 60 percent of the aggregate value of the property

owned by the district or to be acquired or constructed with the proceeds of the bonds proposed to be issued by the district and the reasonable value of the land within the district.

"The foregoing limitation shall not apply to bond issues payable solely from revenues to be received from the proceeds of a contract with a corporation authorized to do business in this State if in the judgment of the commission the proposed revenues will be adequate to service the proposed bond issue, including any reserve fund requirements."

Perusal of available data regarding annual costs of irrigation water in Ventura County indicates a wide range of from about \$5.00 to \$40.00 per acre, with a few exceptions outside of this range. The Federal census report for 1949 shows an average annual cost of water of about \$15.50 per acre for the entire County. Reports issued by the Ventura County Agricultural Extension Service, which include records obtained from all portions of the County, show the following: For 1951, records from 12 lemon groves showed costs of water varying from about \$3 to \$68 per acre, with an average of about \$21 per acre; those from 24 valencia orange groves varying from \$6 to \$101 per acre, with an average of \$37 per acre; and those from 6 walnut groves varying from \$6 to \$17 per acre, with an average of \$9 per acre. For 1949, records from 18 lemon groves showed costs of water varying from \$1 to \$80 per acre, with an average of \$19 per acre; those for 28 valencia orange groves varying from \$6 to \$80 per acre, with an average of \$36 per acre; and those for 16 bean acreages varying from about \$3 to \$56 per acre. Applications of water to the bean crops varied from 9 to 46 acre-inches. However, most of the water costs for the beans averaged from \$5 to \$8 per acre, with an application of from 10 to 14 inches per acre.

It should be understood, however, that higher cost water from new projects for Ventura County would be used only as a supplemental supply and not as an exclusive supply. Therefore, the over-all average cost per acre per year of water applied, local and supplemental, might be low enough to induce the widespread use of a supplemental supply by agriculture.

Adoption of the recommended initial plan under the suggested form of action to be taken would appear to involve the county-wide water district in two approximately simultaneous operations--sale of bonds to the extent of some \$43,000,000--and execution of contracts for water service with subordinating entities that would benefit from construction of the bond-financed works.

Depending upon negotiations with the prospective purchasers of the construction bonds, retirement of them could commence soon after their issuance by levying assessments upon all of the taxable properties in the County and reducing such assessment rates as income from water service contracts commenced to be received, or only bond interest costs could be paid during the initial period of development by levying lower assessments upon all of the taxable property of the County, with no retirement of principal scheduled until income from water service contracts becomes receivable. In the first foregoing instance, the over-all cost of bond service charges probably would be less than in the second instance, but the assessment costs against the taxable properties not directly benefited by the project would be greater.

There is an urgent need for supplemental water to supply the coastal plain of the Santa Clara River Valley. Lands in this area are used so intensively for irrigated agriculture and domestic and industrial purposes that their water needs exceed the ability of the pumped aquifers to transmit supply in sufficient quantity without creation of conditions conducive to the intrusion of sea water to the aquifers. This intensive land use had been made possible only through over-exploitation of the ground water supply and development of a dangerous overdraft. All of the irrigation, domestic, and industrial water users share in the same ground water supply, and all would be adversely affected if sea water were to destroy the utility of the underground basin through continuance of the present overdraft. They are mutually responsible for the present overdraft condition.



Inasmuch as the cost of supplemental water for the coastal plain of the Santa Clara River Valley would be much more than the cost of pumping ground water, and all water users would benefit from such a supply whether or not the supply was used directly, question arises as to determining some equitable criterion under which all water users would share in the added cost of the supplemental supply. An answer to this question might lie in the adoption of a method similar to that now being undertaken by the Orange County Water District. It has become evident to the people of Orange County, after some 25 years of effort and failure, that the encroachment of sea water and the eventual ruin of their ground water resources cannot be prevented by uncoordinated, piecemeal efforts. They have apparently decided that some effective agency must be given the power to manage and operate the ground water recharge program, to collect sufficient taxes on some reasonably equitable basis to pay for the necessary imported supplemental water, and to administer the program. Senate Bill No. 91, passed by the Legislature in May, 1953, broadens the powers of the existing Orange County Water District to accomplish this program. The bill provides, among other things, for the assessment of land and improvements, for a pumpage tax on water extracted from the basin, called a "replenishment assessment", and for registration and control of all water-producing facilities.

If the principle of the foregoing Orange County method were adopted in Ventura County, a pumpage tax could be levied against all ground water users in a given basin on the basis of annual water production. For illustrative purposes, alternative methods for fixing these charges in the coastal plain of the Santa Clara River Valley are described. It is believed that these methods could be generally applicable throughout the County.

It is estimated in this bulletin that the mean seasonal pumpage in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Subunits approximates 35,000 acre-feet. Of this amount, under the recommended plan of water

development, about 44,000 acre-feet of supplemental water would be supplied by surface conduit to a portion of the area presently served from ground water. However, the present cost of ground water supplies is appreciably cheaper than would be the cost of the supplemental supply.

Assuming that all water users in the area are mutually responsible for the overdraft condition, and therefore should bear all costs of alleviating this condition proportionately, then that portion of the water users continuing to utilize the ground water supplies would, in addition to paying for the cost of pumping ground water, also pay a pumpage tax. This tax, based on a per acre-foot of pumped water, would be sufficiently high to raise funds with which to purchase the necessary supplemental supply and would be used by the local water district to subsidize the users of the supplemental surface supply to the extent that all users in the area of overdraft would pay about the same unit cost for water.

An alternative to the foregoing method would be to levy an ad valorem tax on the real property, the revenue from which would be used to reduce the amount of the required pumpage tax. If an ad valorem tax were levied at the rate of, say, \$1 per \$100 of assessed valuation, and if a total assessed valuation of \$40,000,000 for the area be assumed, the annual income from this source to be applied on the annual cost of the supplemental supply would amount to about \$400,000. Thus, the required pumpage tax on ground water users would be reduced and, similarly, the 44,000 acre-feet of supplemental water could be sold at a lower price.

There is considerable justification for employing a combination water toll and assessment method as a means of raising the required revenue for supplemental water. In many cases, high-value properties in urban and industrial areas have a relatively small water requirement. Nevertheless, they benefit substantially from the intensive agriculture that is prevailing in the

surrounding area, by furnishing goods and services to the farmer in his crop production and marketing. An increase in over-all water costs to the operators of such high-value properties would not increase their costs of doing business nearly as much as it would to the farmer.

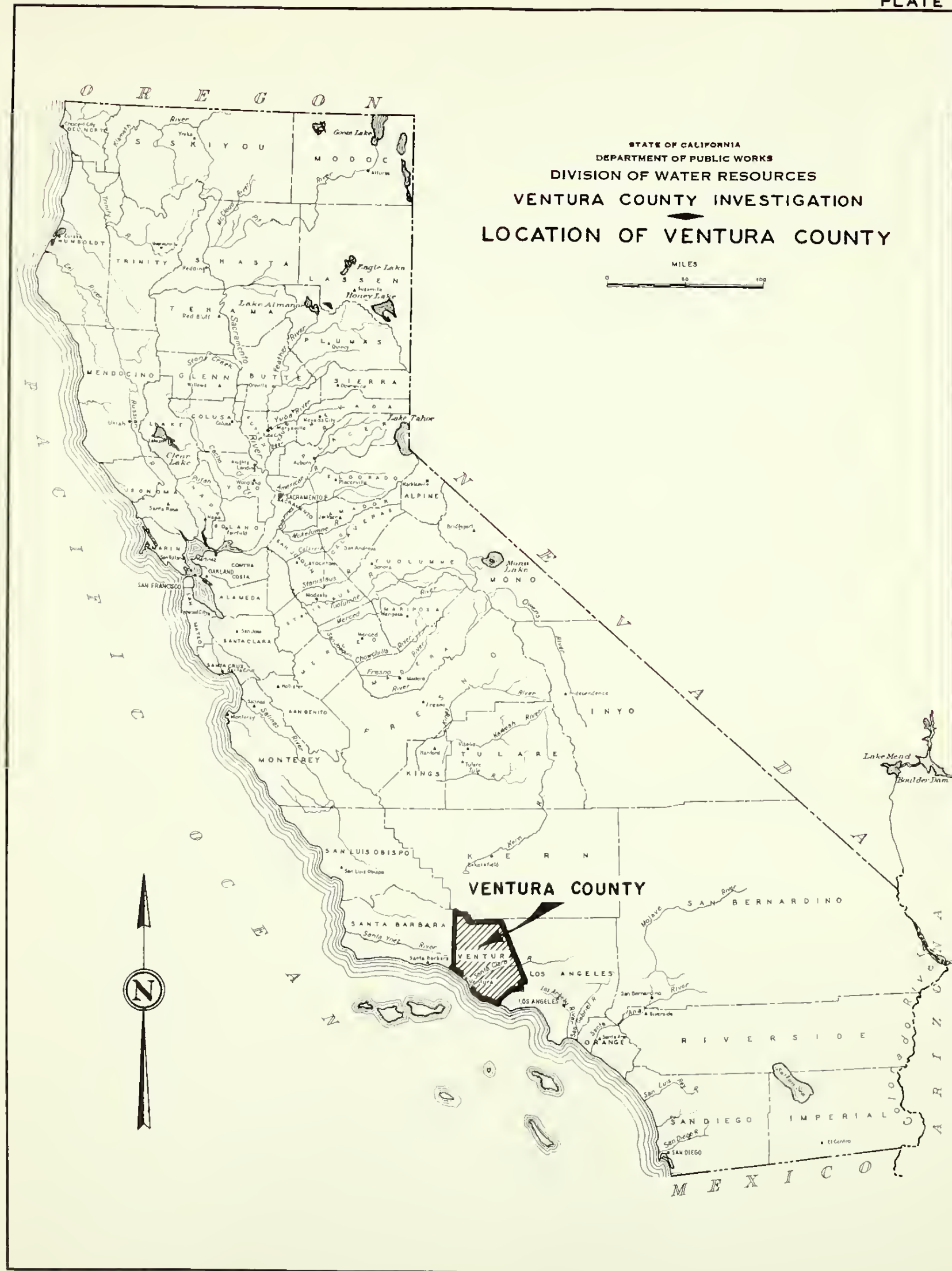
In lieu of levying an assessment upon the real property described above, increased unit cost rates for water could be charged to the nonagricultural users. For instance, of the total seasonal delivery requirement of 35,000 acre-feet of water for the coastal plain of the Santa Clara River Valley, it is estimated that about 10,000 acre-feet per season of supplemental water could be sold to urban entities. Therefore, if one arbitrarily assumes an average cost of \$20 per acre-foot to pump 41,000 acre-feet and to make available a supplemental supply of 44,000 acre-feet, then 10,000 acre-feet of the supplemental supply might be sold for possibly \$50 per acre-foot for urban use. Thus, the average annual cost of the remaining 75,000 acre-feet of water utilized could be reduced from \$20 to about \$16 per acre-foot.

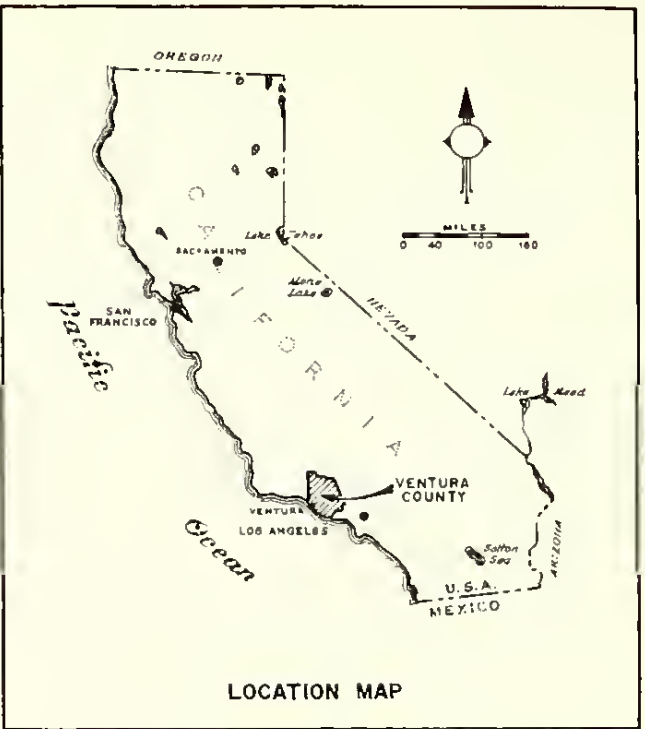
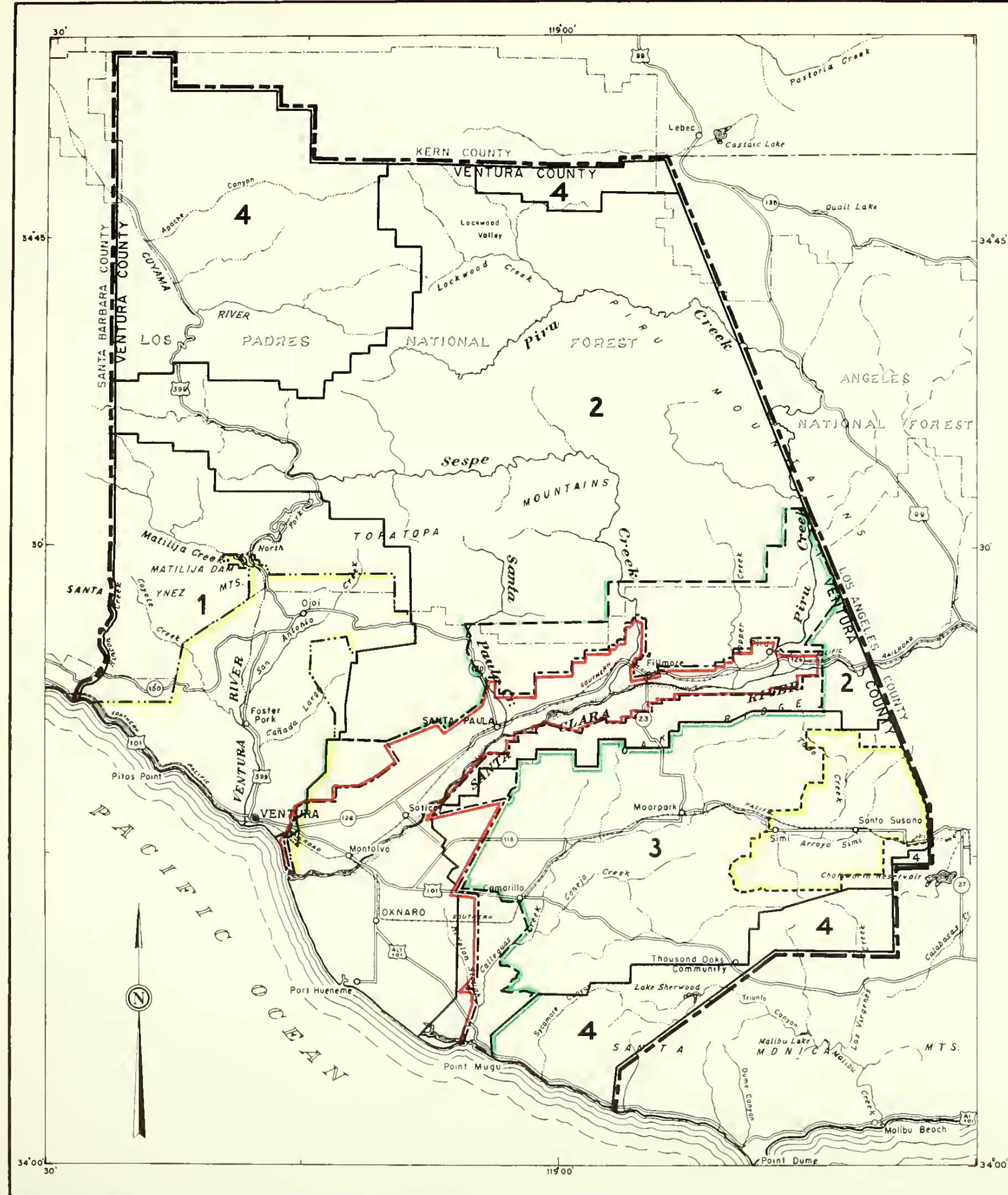
The foregoing suggested methods of financing supplemental water supplies for the Santa Clara River Hydrologic Unit could be undertaken by the United Water Conservation District if granted certain additional powers. It is not believed that this District now has the power to implement any kind of a program that would be based upon a pumpage tax. Therefore, authority would have to be requested of the Legislature for it to do so, as has been done by the Orange County Water District. Also, the financing programs could probably be carried out by an adequately empowered improvement district created within the United Water Conservation District.

A factor that should enhance the security of any general obligation bonds that would be presently issued in Ventura County is the probable future rate of increase in assessed values. During the past 10 years, from 1944-45



to 1953-54, inclusive, total assessed values have increased an average of \$17,700,000 yearly. If only a \$10,000,000 increase annually occurred in the future, there would be an aggregate increase of \$100,000,000 a decade hence. With partial rectification of present adverse water supply conditions, such future growth in valuation does not appear unlikely.



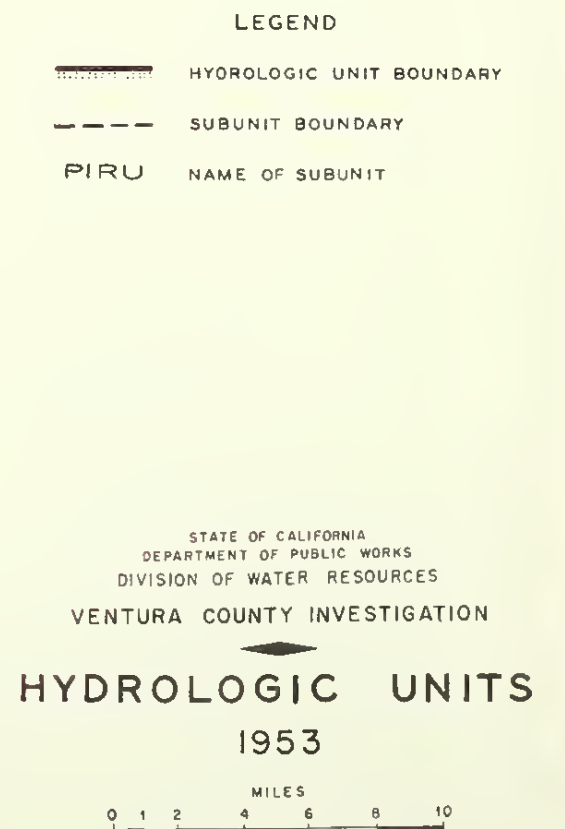
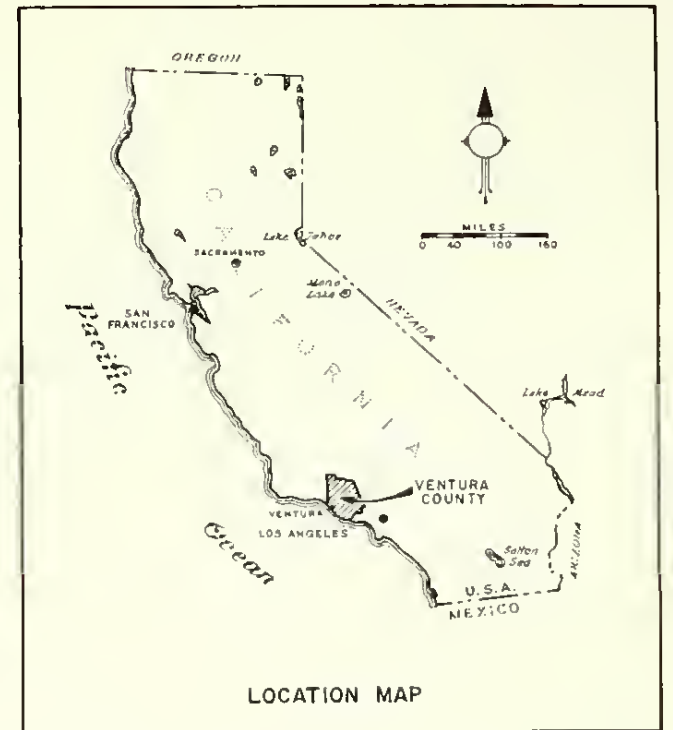
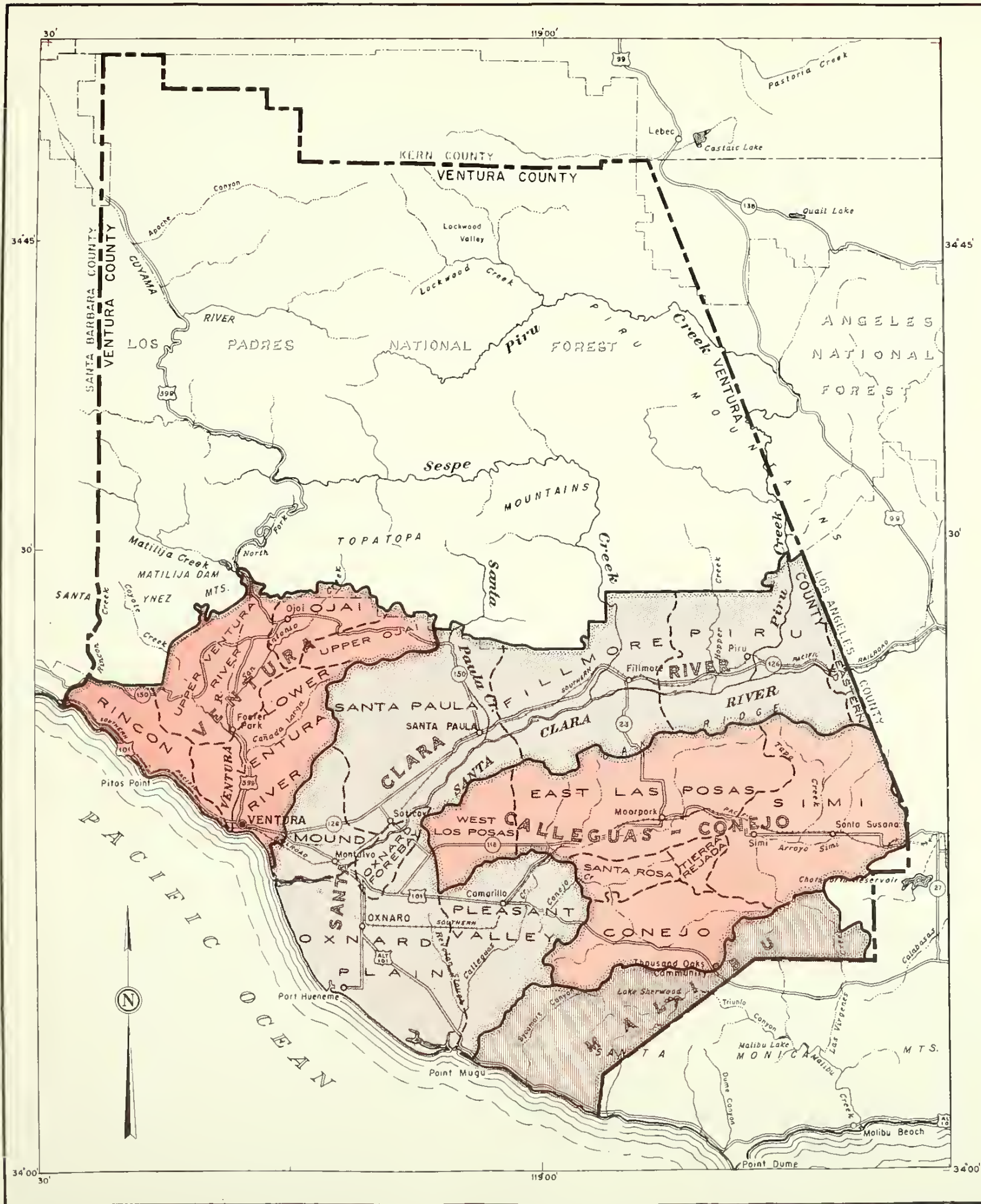


- LEGEND
- BOUNDARY OF VENTURA COUNTY FLOOD CONTROL DISTRICTS BY ZONES
  - 4 FLOOD CONTROL DISTRICT ZONE NUMBER
  - BOUNDARY OF SANTA CLARA WATER CONSERVATION DISTRICT
  - BOUNDARY OF UNITED WATER CONSERVATION DISTRICT
  - BOUNDARY OF VENTURA RIVER MUNICIPAL WATER DISTRICT
  - BOUNDARY OF SIMI VALLEY WATER CONSERVATION DISTRICT

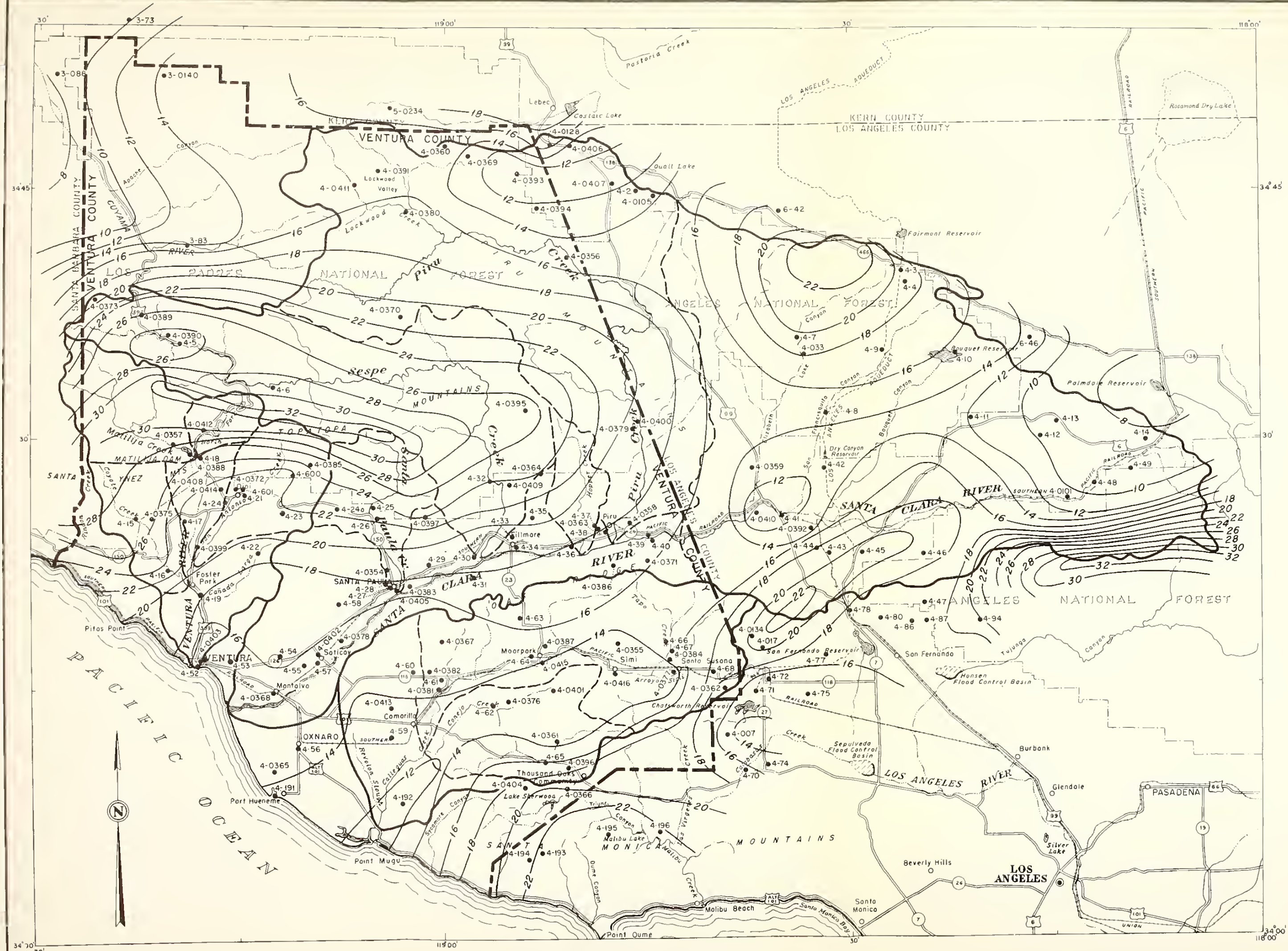
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**MAJOR WATER DISTRICTS**  
1953











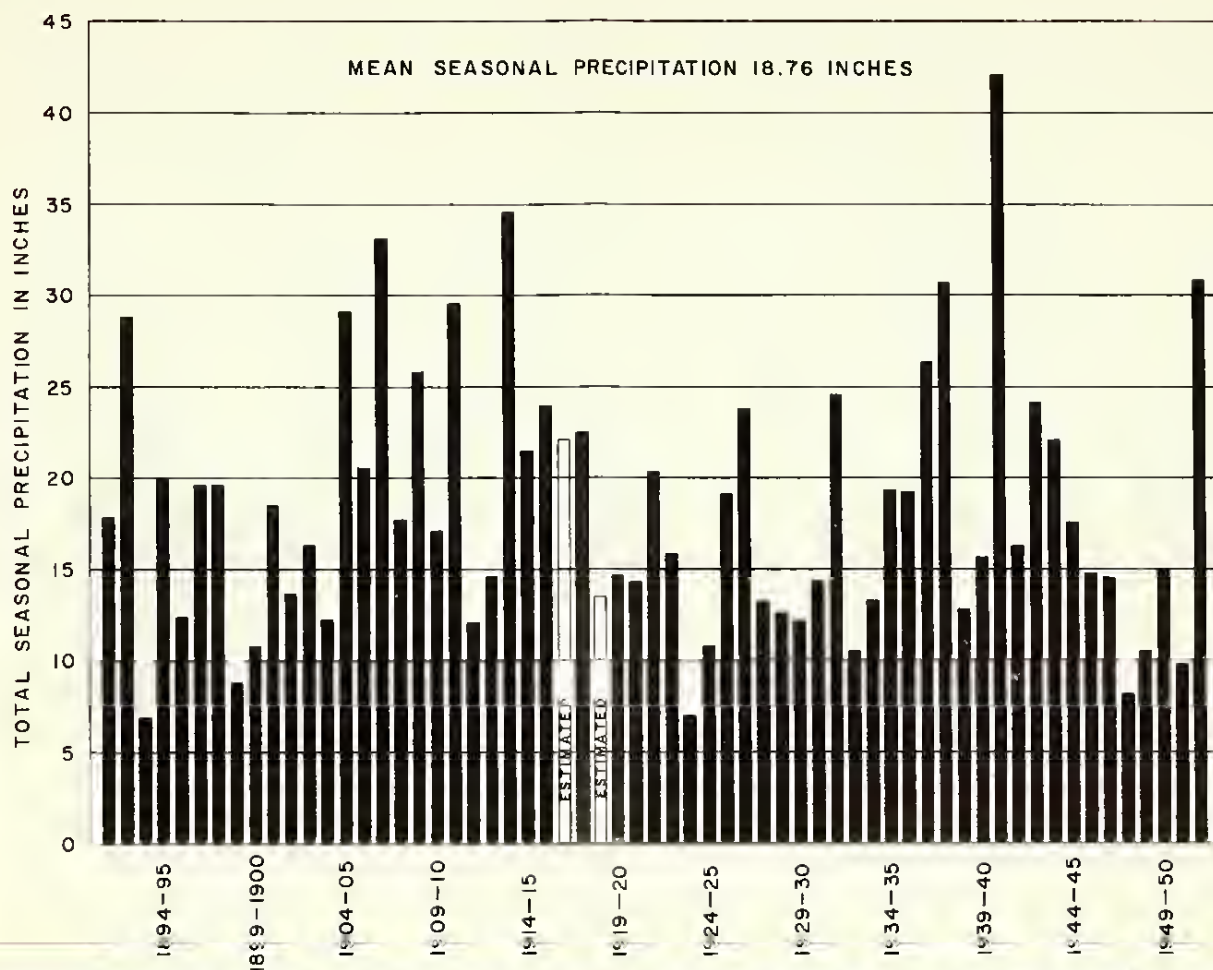
- LEGEND
- PRINCIPAL ORAINAGE AREA BOUNDARY
  - - - SECONDARY ORAINAGE AREA BOUNDARY
  - 12 — LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES
  - PRECIPITATION STATION

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DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

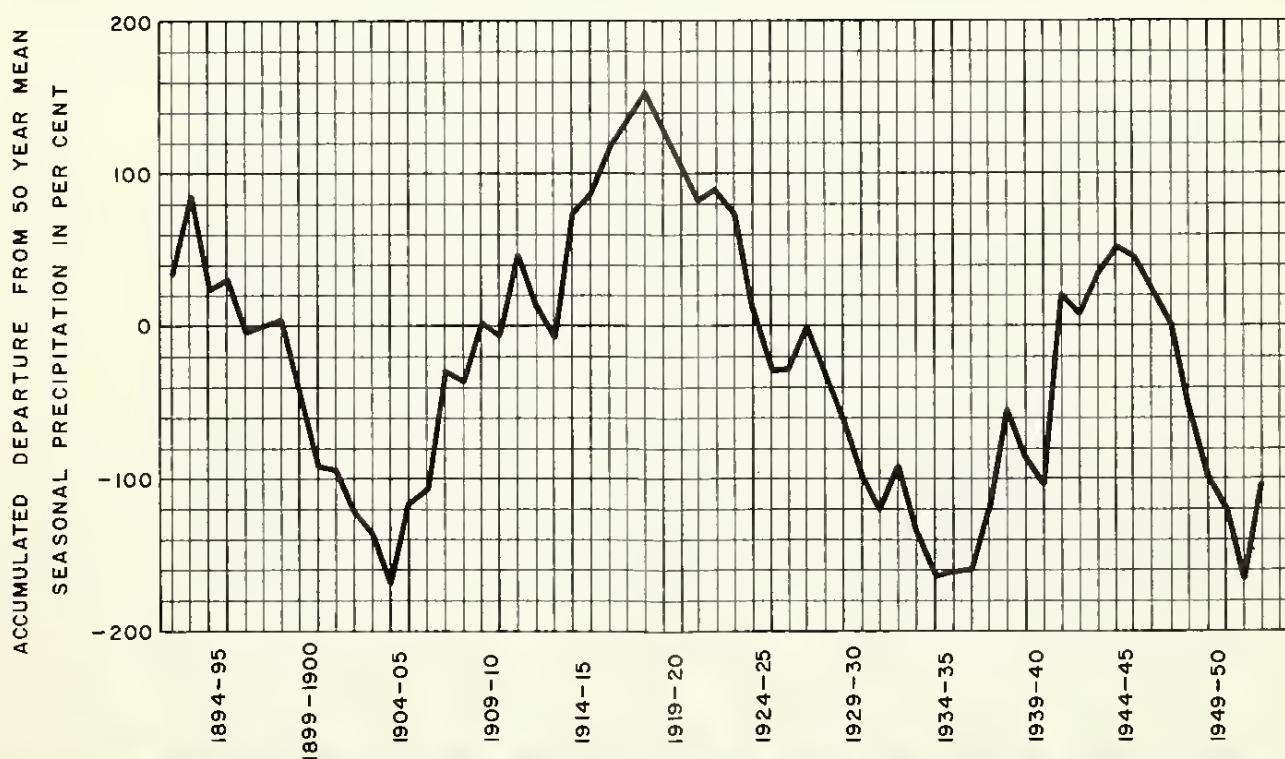
**Lines of Equal Mean Seasonal  
Precipitation in Inches  
1897-98 through 1946-47**

0 2 4 6 8 10  
MILES



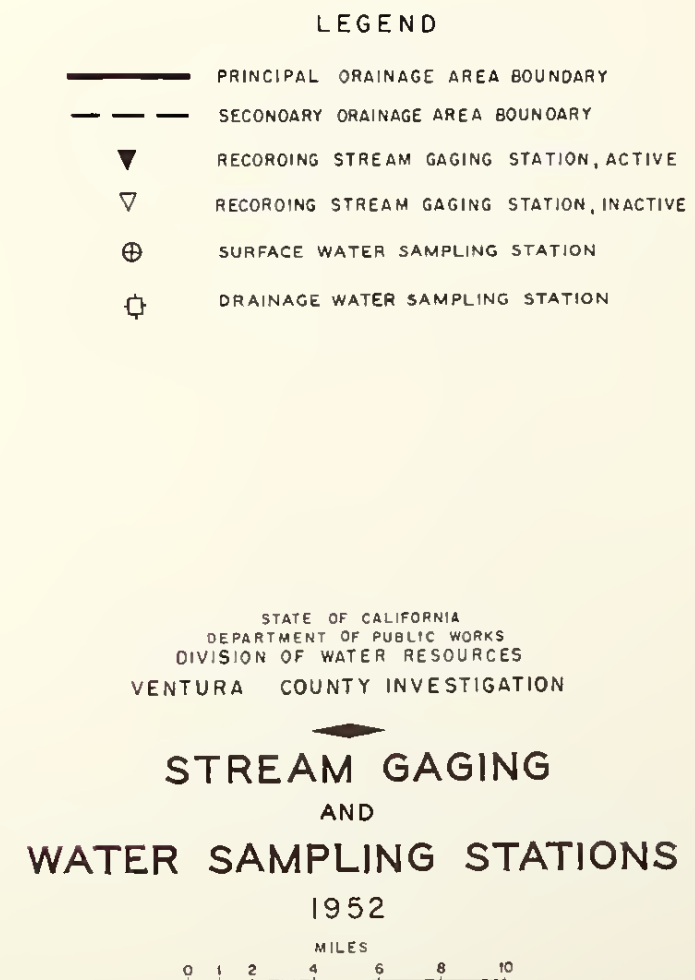
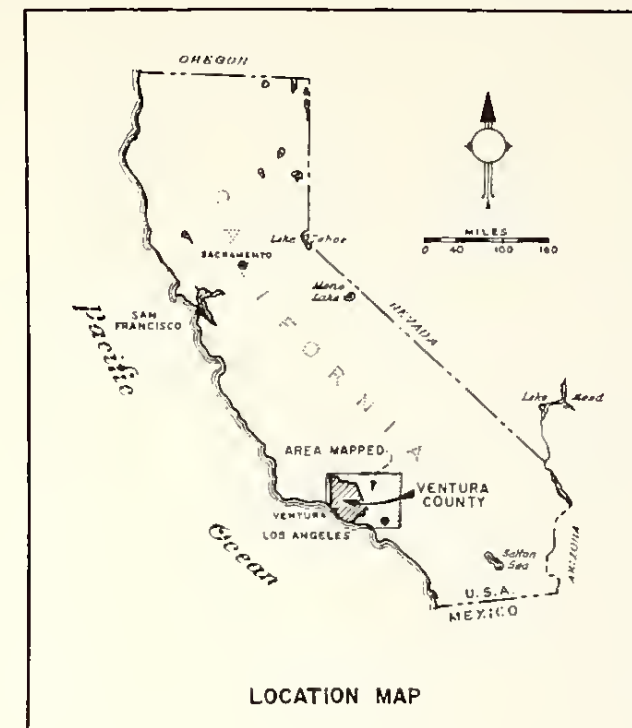
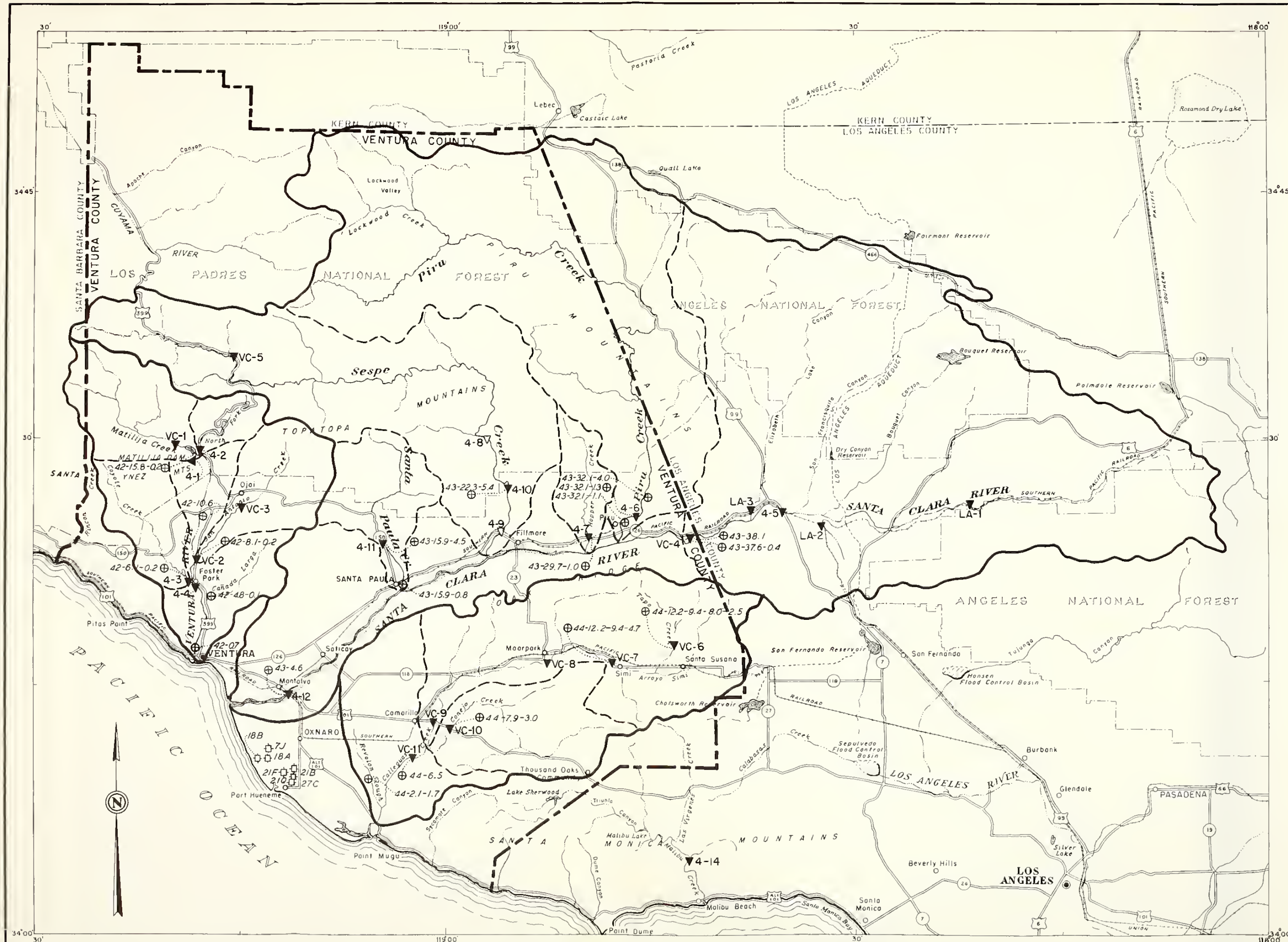


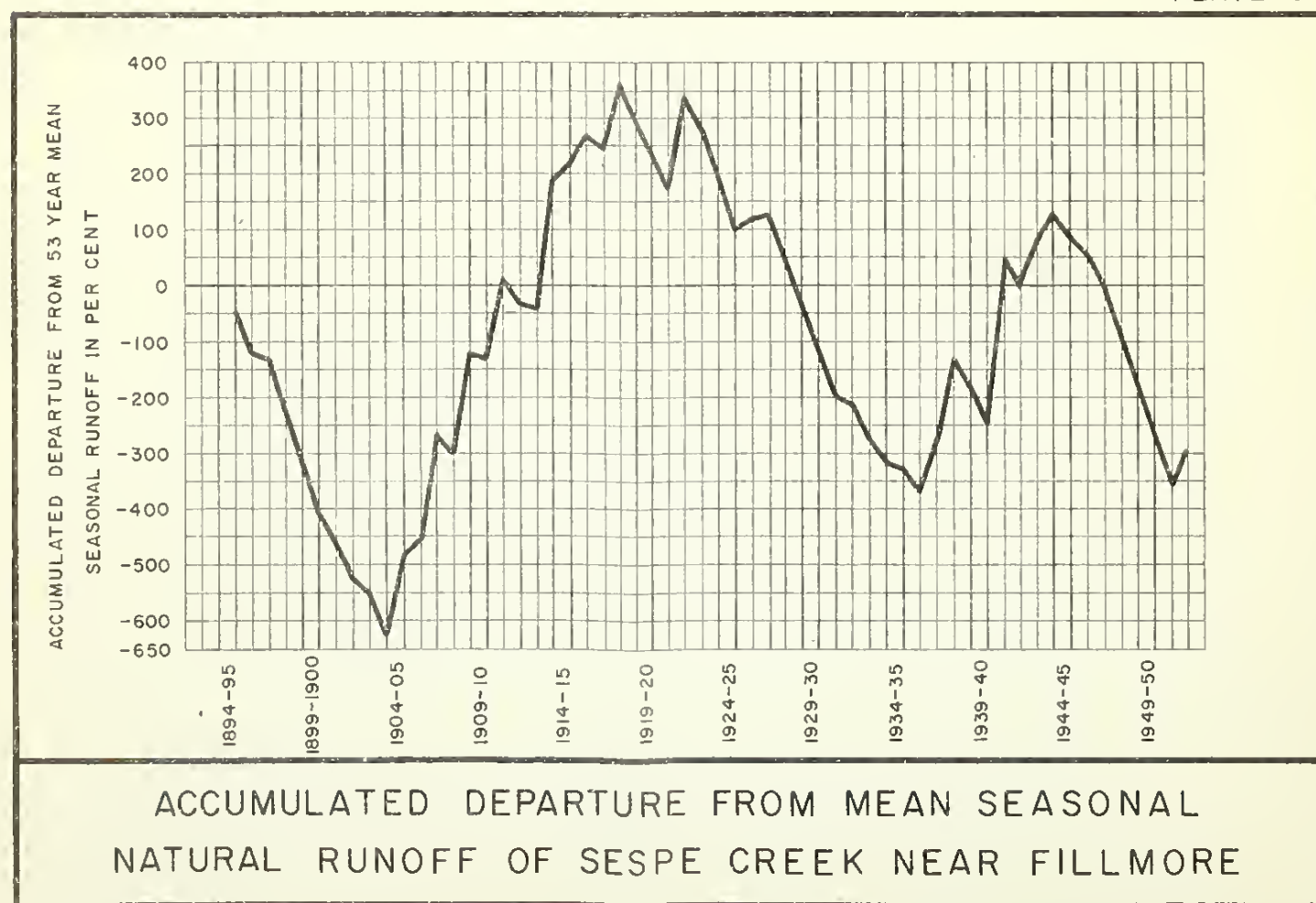
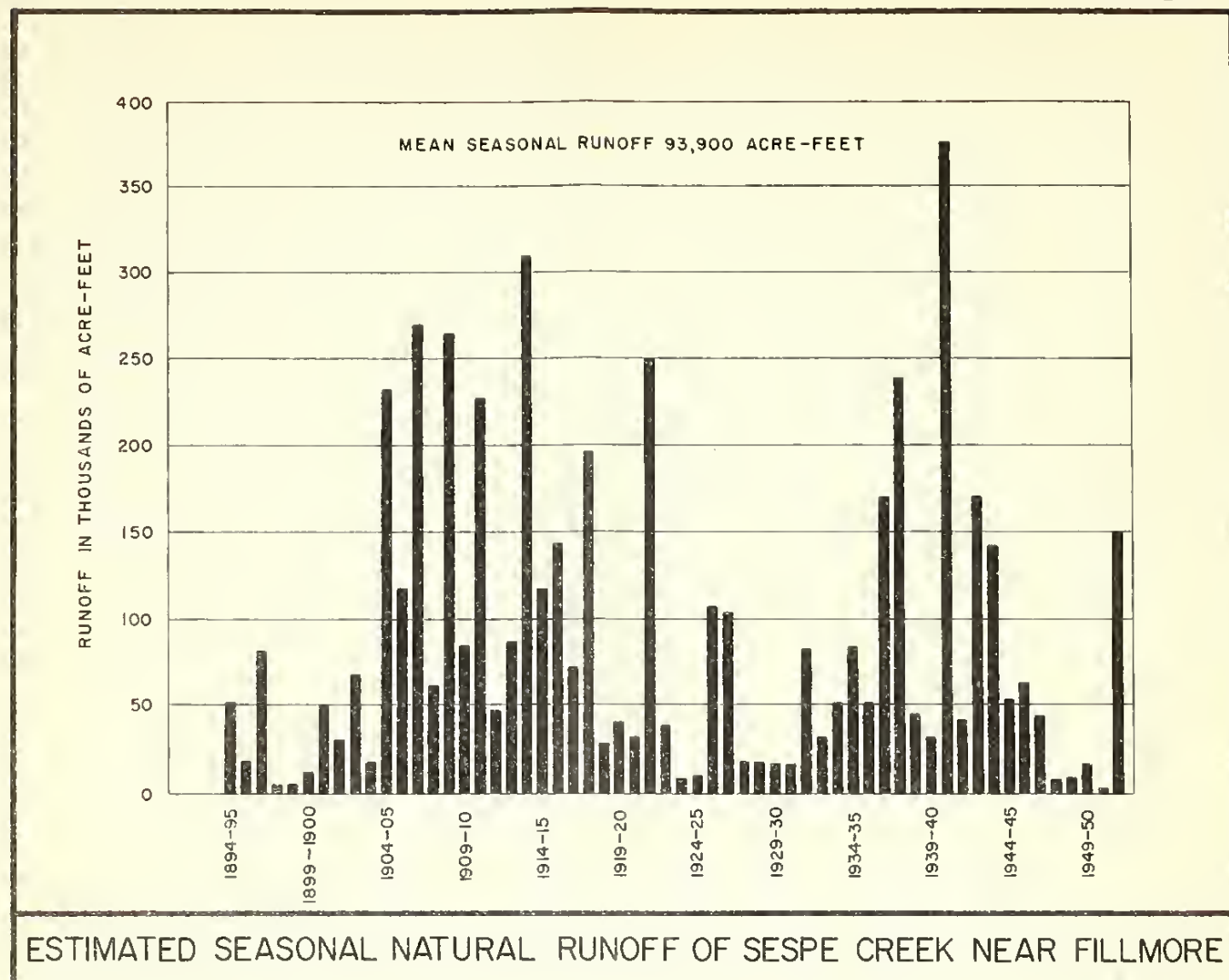
RECORDED SEASONAL PRECIPITATION AT OJAI



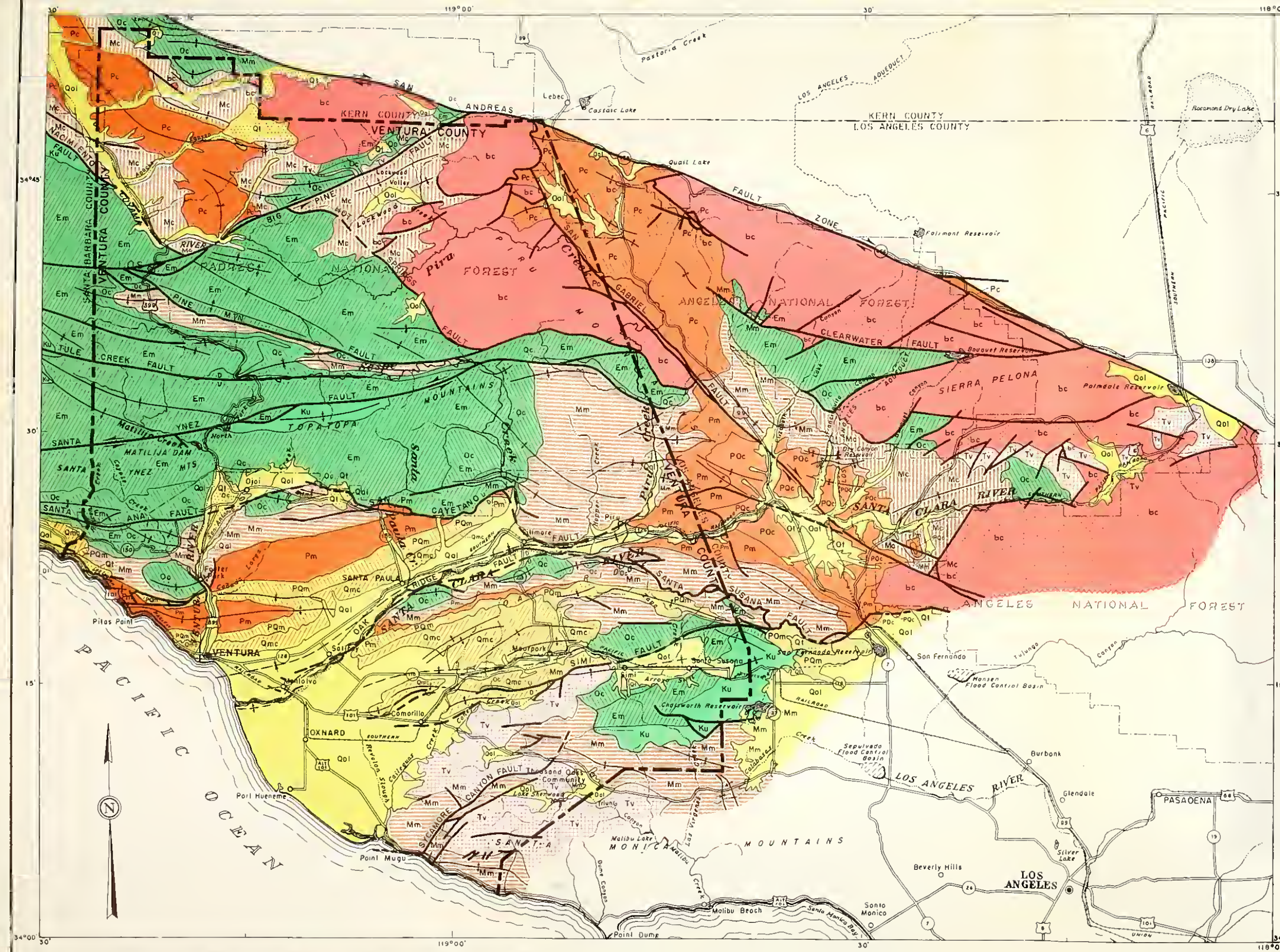
ACCUMULATED DEPARTURE FROM MEAN SEASONAL PRECIPITATION AT OJAI











— GEOLOGIC LEGEND —

SEDIMENTARY FORMATIONS

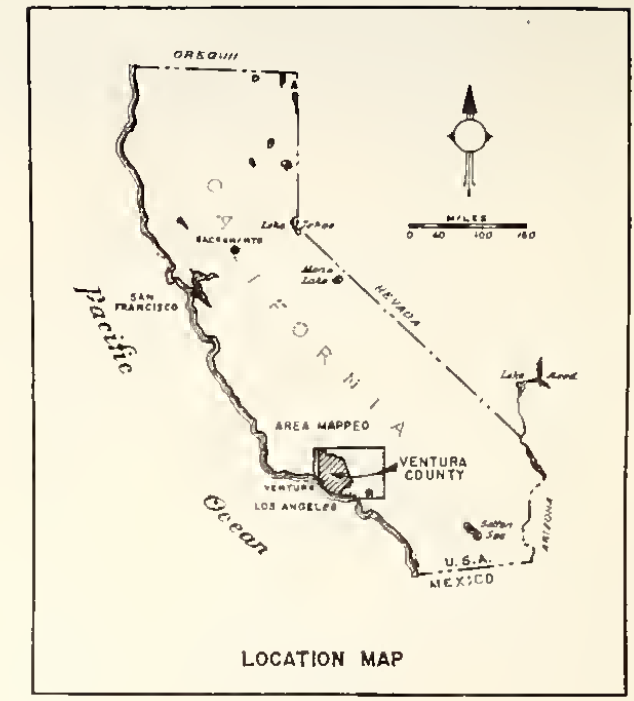
- RECENT
- Qal ALLUVIUM  
SAND, GRAVEL AND CLAY IN STREAM CHANNELS AND FLOOD PLAINS. SUPPLIES MANY WELLS.
  - Ql TERRACE DEPOSITS AND OLDER ALLUVIUM  
GRAVEL, SAND AND CLAY. GENERALLY HIGHLY PERMEABLE, SUPPLIES MANY WELLS.
- PLEISTOCENE
- Qmc SAN PEDRO FORMATION  
SAND, GRAVEL AND CLAY. MARINE AND CONTINENTAL. PERMEABLE ZONES SUPPLY MANY WELLS; INCLUDES FOX CANYON MEMBER WHICH YIELDS CONSIDERABLE WATER OF GOOD QUALITY IN THE LAS POSAS AND PLEASANT VALLEY AREAS.
  - PQm SANTA BARBARA FORMATION  
MARINE MUDSTONE, SHALE, SANDSTONE, SAND, GRAVEL AND CLAY. NONWATER-BEARING EXCEPT FOR GRIMES CANYON MEMBER WHICH SUPPLIES SOME WELLS IN THE LAS POSAS-PLEASANT VALLEY AREA.
- PLIOCENE
- PQc SAUGUS FORMATION  
SAND, SLIGHTLY CEMENTED GRAVEL AND CLAY. CONTAINS MODERATELY PERMEABLE STRATA; YIELDS WATER TO FEW WELLS.
  - Pm PICQ FORMATION  
MARINE SANDSTONE, SHALE, LENSES OF CONGLOMERATE. GENERALLY NONWATER-BEARING OR CONTAINS SALTY WATER.
  - Pc RIDGE BASIN GROUP AND MORALES FORMATION  
CONTINENTAL SHALE, SANDSTONE, CONGLOMERATE, GRAVEL AND SAND. CONTAINS UNDEVELOPED PERMEABLE ZONES.
- MIOCENE
- Mm SANTA MARGARITA, MODELO, RINCON AND VADUEROS FORMATIONS  
MARINE SANDSTONE AND SHALE, SOME CONGLOMERATE AND CLAY. GENERALLY NONWATER-BEARING OR CONTAINS BRACKISH WATER. LOCALLY PROVIDES LIMITED QUANTITIES OF FRESH WATER TO WELLS.
  - Mc MINT CANYON AND QUATAL FORMATIONS  
NON-MARINE SANDSTONE, CONGLOMERATE, GYPSIFEROUS CLAY AND SOME MARL. GENERALLY NONWATER-BEARING.
- OLIGOCENE
- Oc SESPE, SIMMLER AND VASQUEZ FORMATIONS  
NON-MARINE SANDSTONE, CONGLOMERATE AND SHALE. GENERALLY NONWATER-BEARING OR CONTAINS BRACKISH WATER; SUPPLIES FEW WELLS LOCALLY.
- Eocene and PALEOCENE
- Em UNDIFFERENTIATED EOCENE AND PALEOCENE FORMATIONS  
MARINE SANDSTONE, SHALE AND CONGLOMERATE. PERMEABLE ZONES YIELD LIMITED QUANTITIES OF VARIABLE QUALITY WATER.
  - Ku UNDIFFERENTIATED MARINE FORMATIONS  
SANDSTONE, SHALE AND LITTLE CONGLOMERATE. PERMEABLE ZONES IN SOME AREAS YIELD WATER OF VARIABLE QUALITY IN LIMITED AMOUNT.

IGNEOUS AND METAMORPHIC ROCKS

- Tv VOLCANIC FLOWS, PYROCLASTICS, AND SHALLOW INTRUSIVES  
YIELDS VARIABLE QUANTITIES OF WATER TO WELLS; IMPORTANT WATER SOURCE IN SANTA ROSA, TIERRA REJADA AND CONEJO AREAS.
- bc BASEMENT COMPLEX  
GRANITIC AND METAMORPHIC ROCKS. NONWATER-BEARING EXCEPT FOR LIMITED QUANTITIES OF WATER DERIVED FROM FISSURES OR WEATHERED ZONES.

- FAULT, SURFACE TRACE
- - - FAULT, BURIED OR INFERRED
- + + + AXIS OF ANTICLINE } DASHED WHERE BURIED
- - - + - - - AXIS OF SYNCLINE
- FORMATION CONTACT

COMPILED IN 1953 FROM FIELD MAPPING BY THE STATE DIVISION OF WATER RESOURCES AND FROM PUBLISHED AND UNPUBLISHED MAPS ACKNOWLEDGED IN THE ACCOMPANYING TEXT

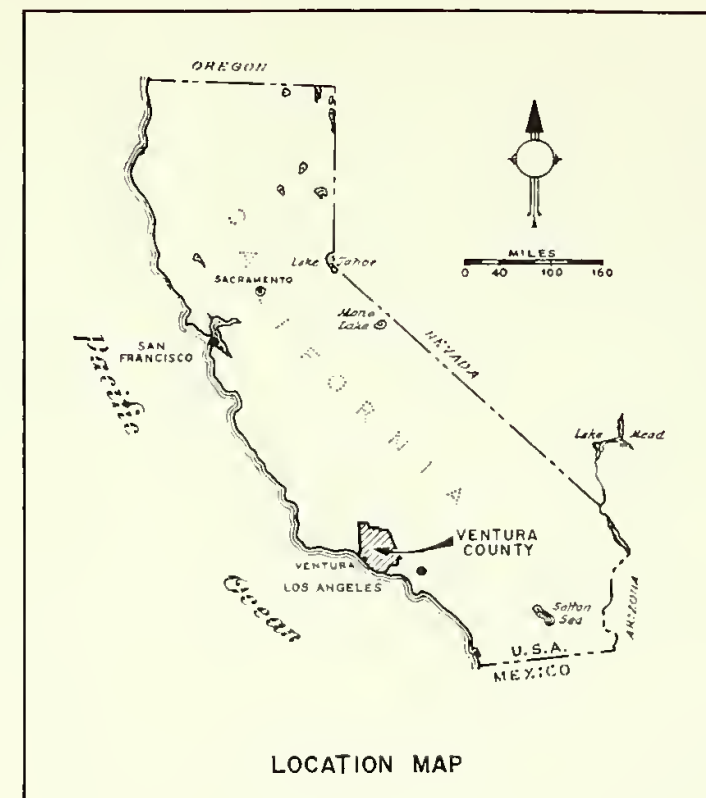
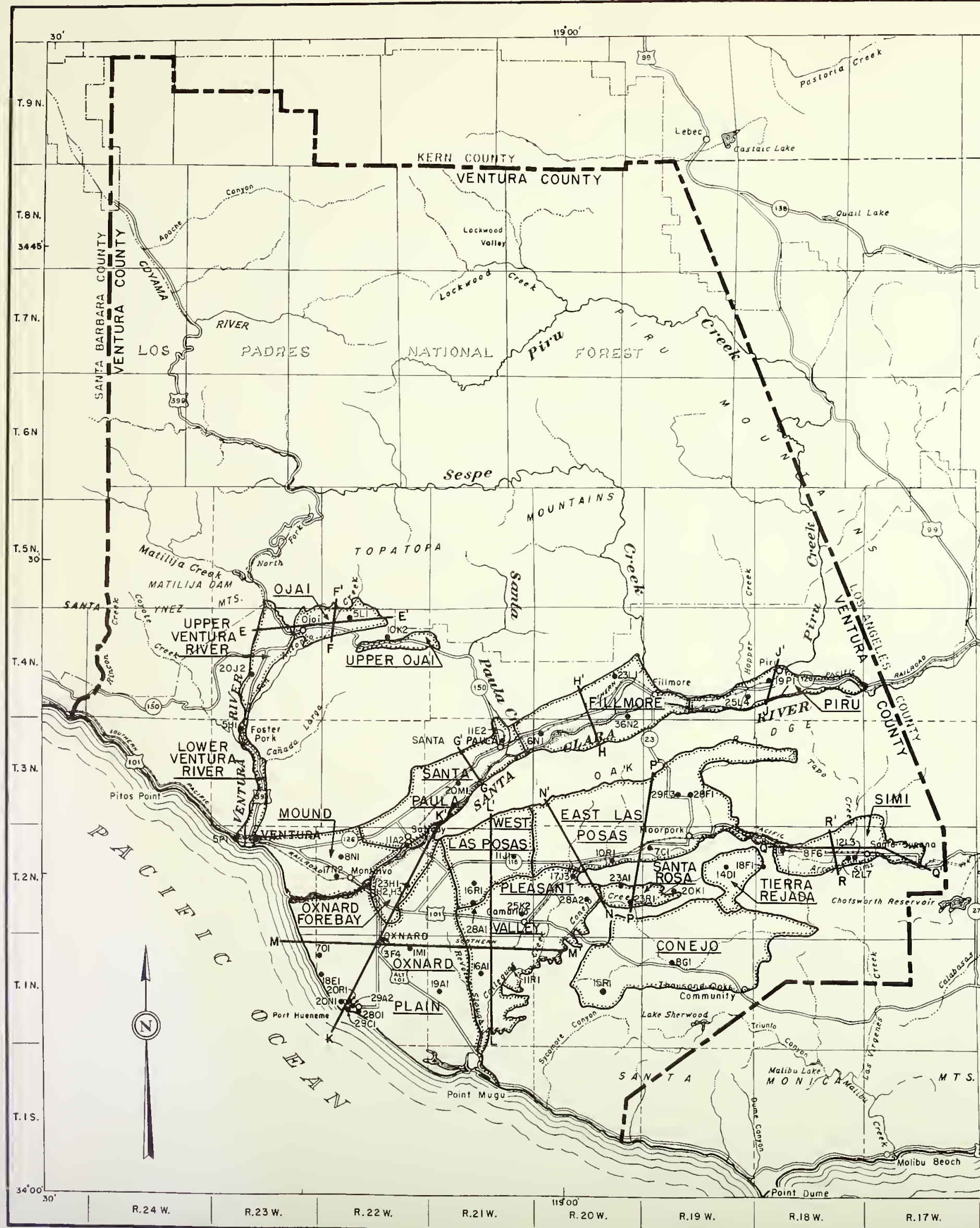


STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

AREAL GEOLOGY  
1953

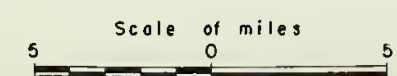




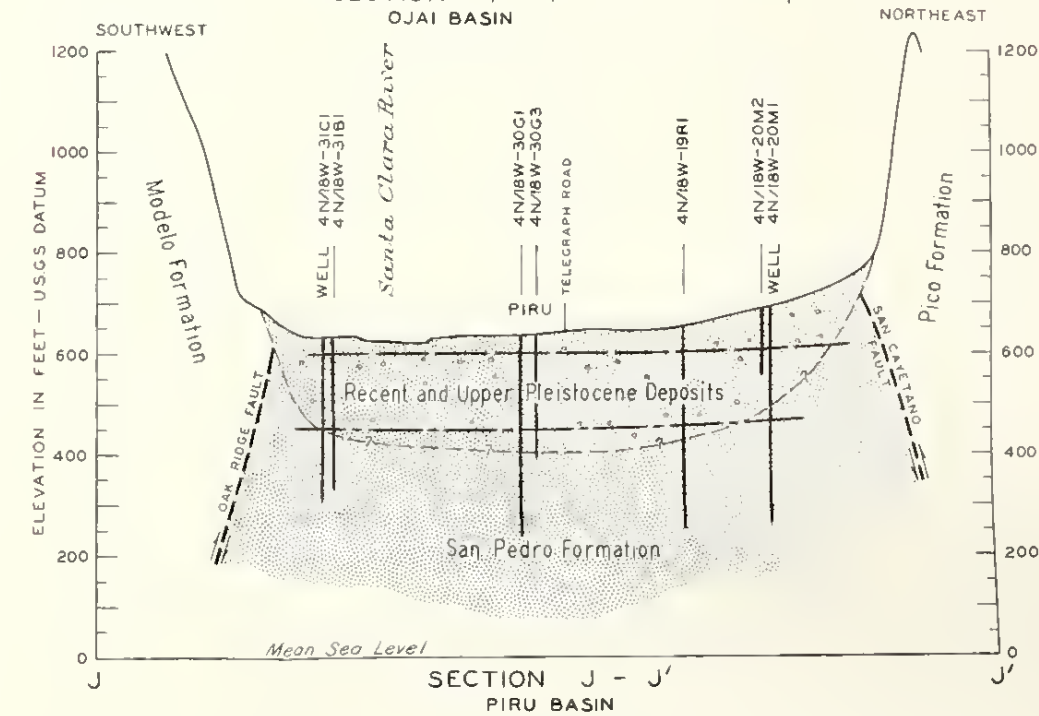
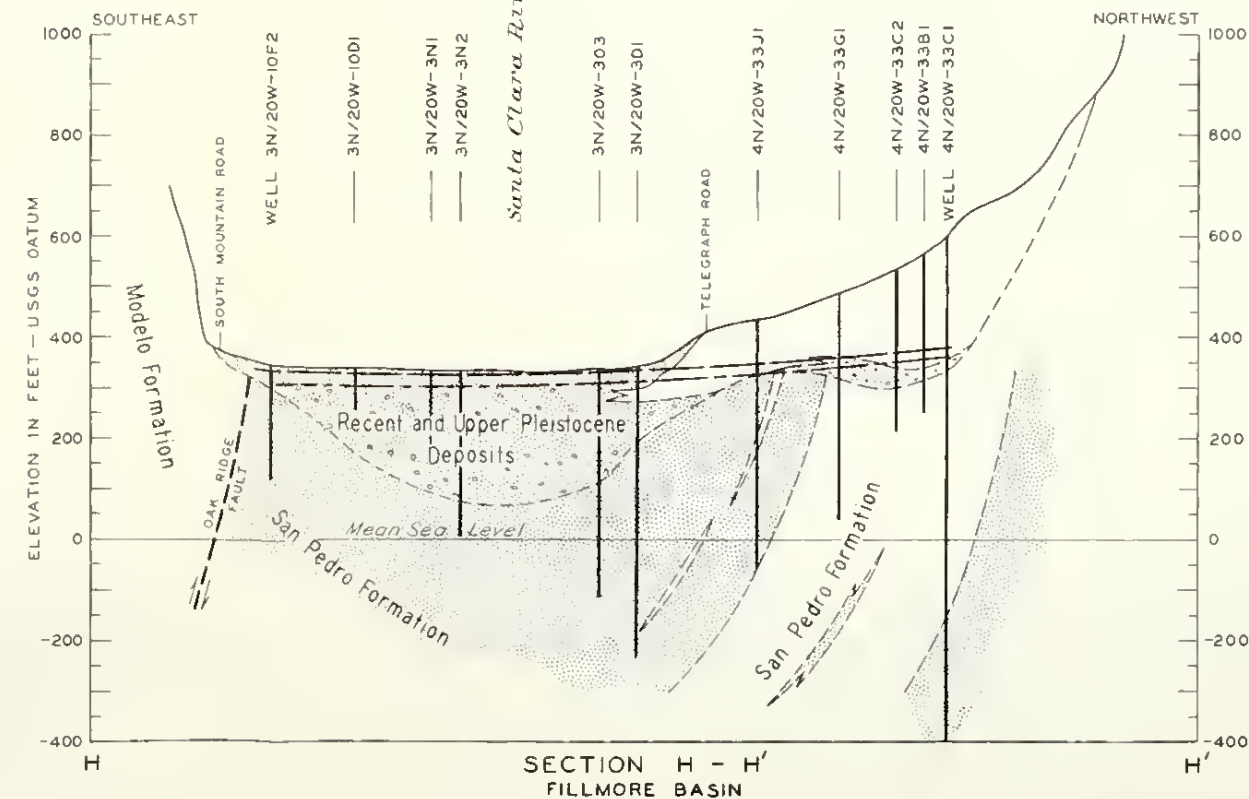
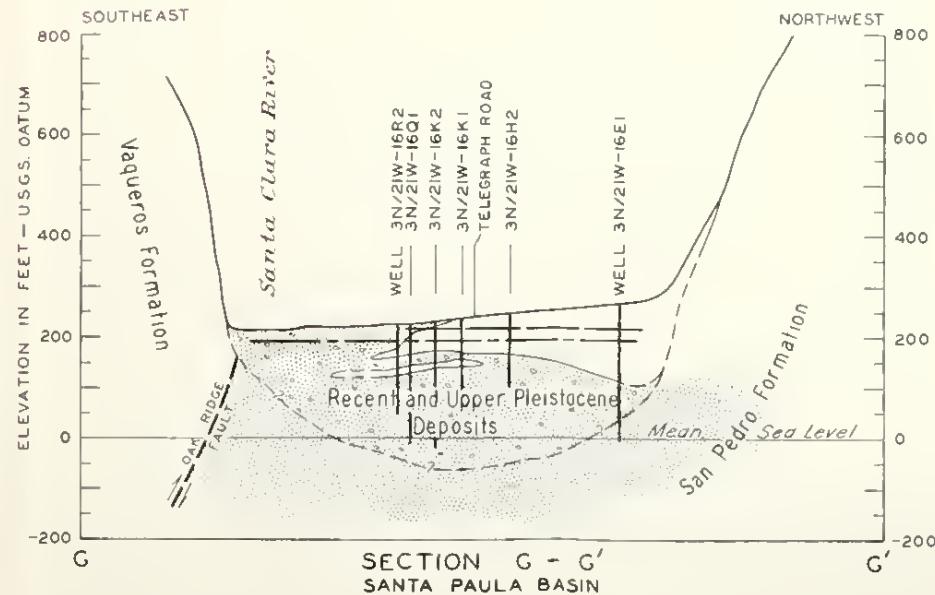
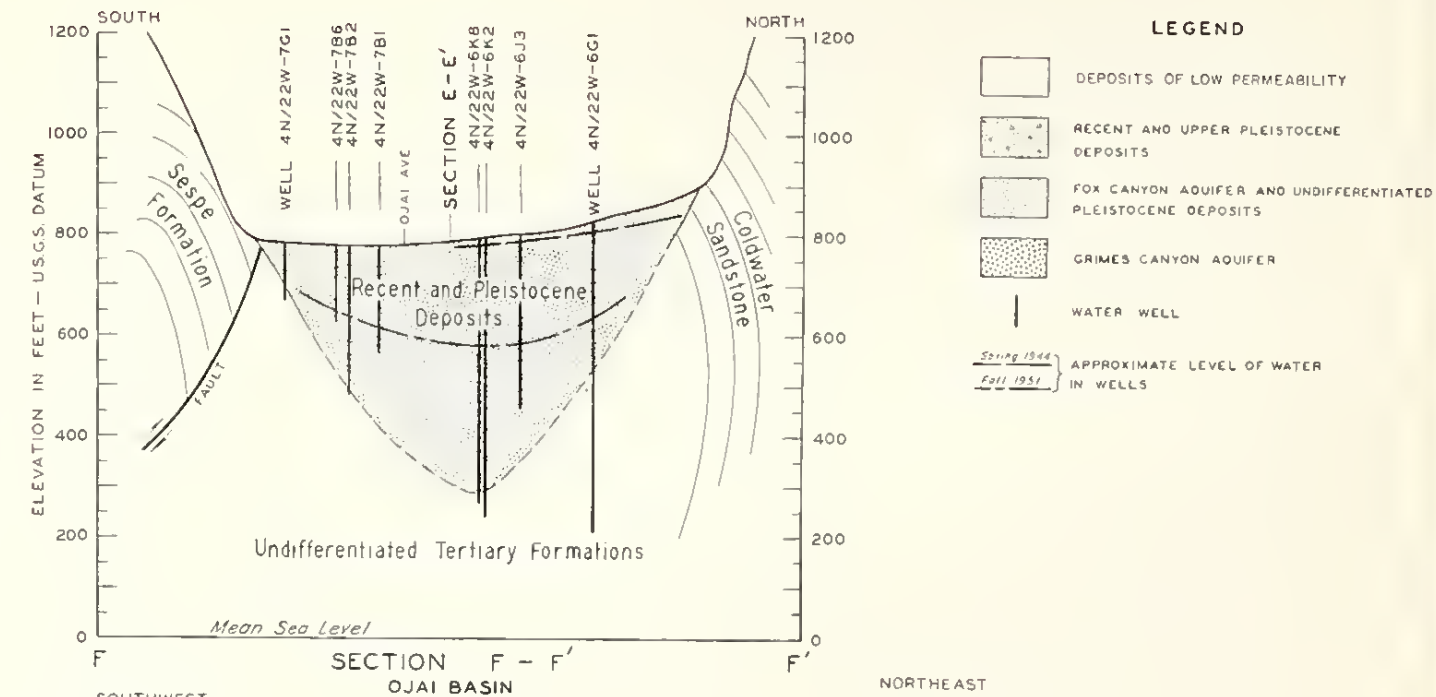
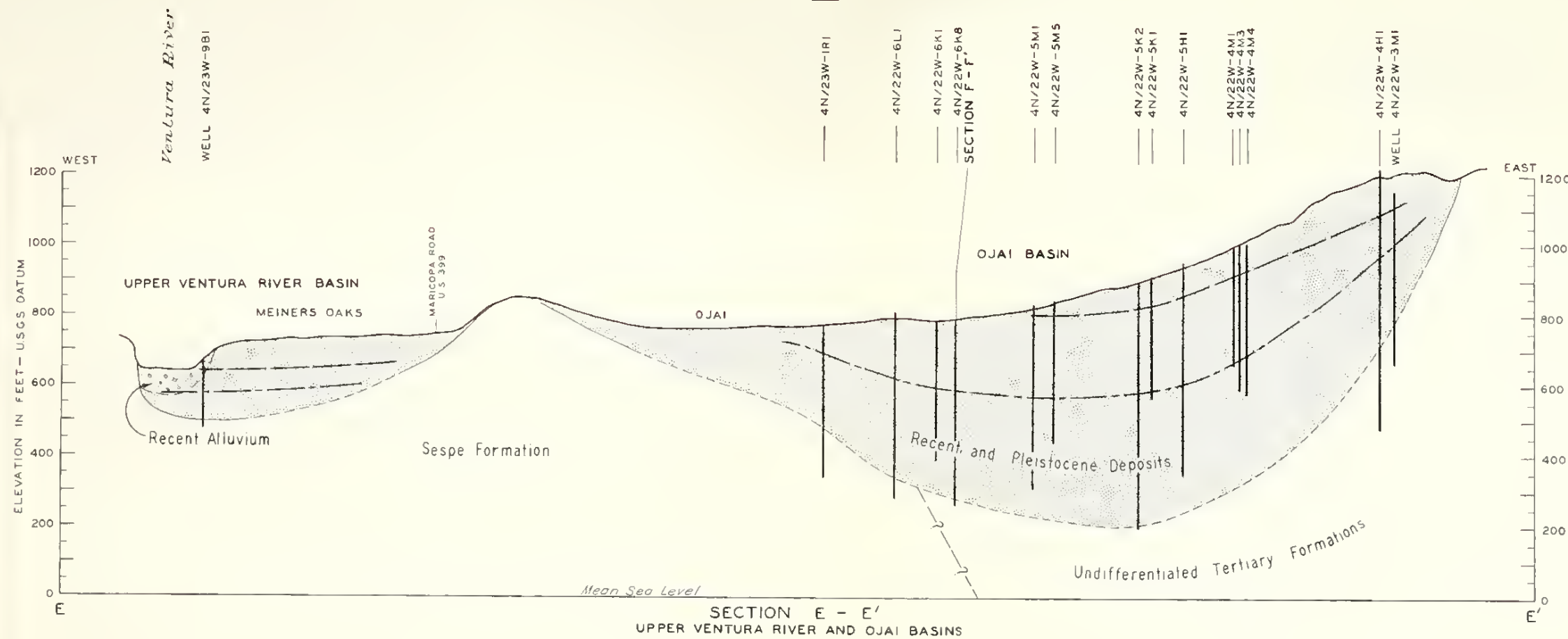


- LEGEND
- GROUND WATER BASIN BOUNDARY
  - 35N1 KEY WELL
  - E' LINE OF GEOLOGIC SECTION

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**GROUND WATER BASINS**  
1953







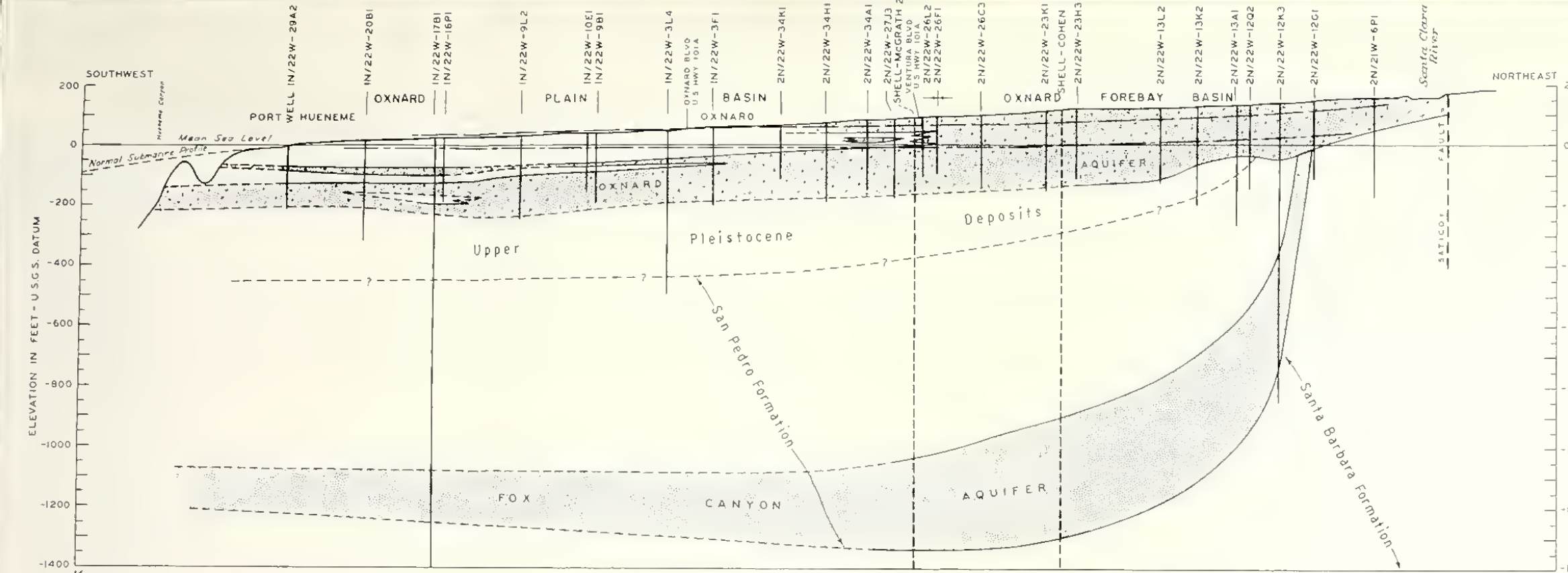
- LEGEND**
- DEPOSITS OF LOW PERMEABILITY
  - RECENT AND UPPER PLEISTOCENE DEPOSITS
  - FOX CANYON AQUIFER AND UNDIFFERENTIATED PLEISTOCENE DEPOSITS
  - GRIMES CANYON AQUIFER
  - WATER WELL
  - APPROXIMATE LEVEL OF WATER IN WELLS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

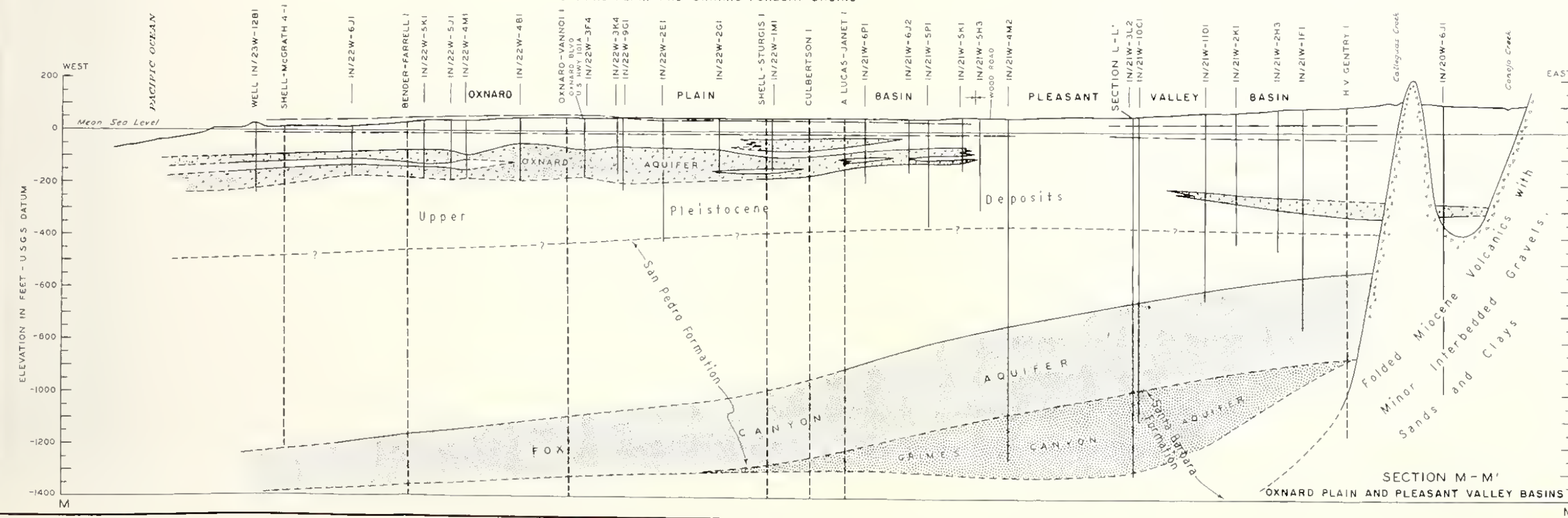
**GEOLOGIC SECTIONS  
E-E', F-F', G-G', H-H' AND J-J'**  
1953



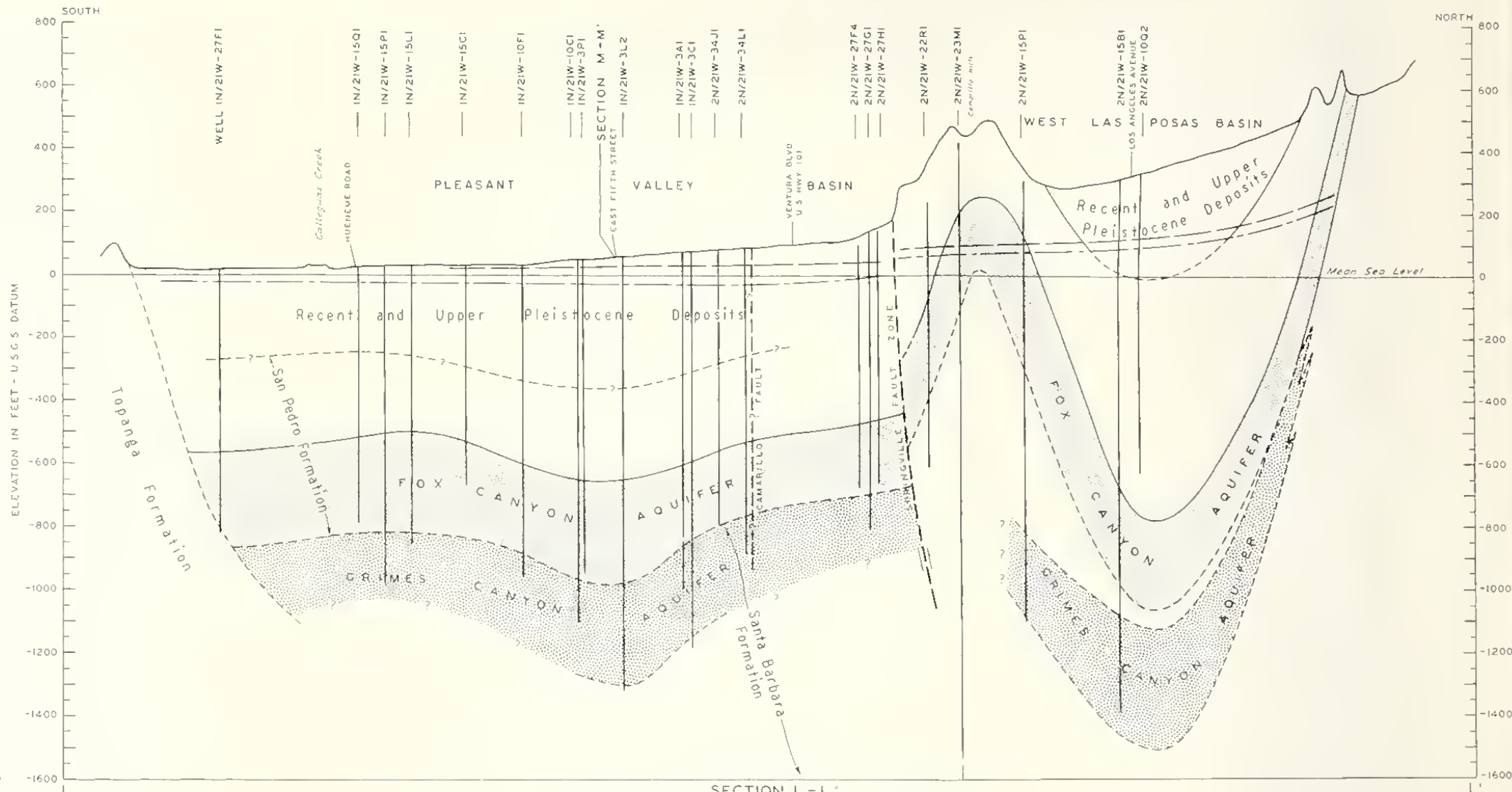




SECTION K-K'  
OXNARD PLAIN AND OXNARD FOREBAY BASINS



SECTION M-M'  
OXNARD PLAIN AND PLEASANT VALLEY BASINS



SECTION L-L'  
PLEASANT VALLEY AND WEST LAS POSAS BASINS

- LEGEND
- DEPOSITS OF LOW PERMEABILITY
  - RECENT AND UPPER PLEISTOCENE DEPOSITS
  - FOX CANYON AQUIFER AND UNDIFFERENTIATED PLEISTOCENE DEPOSITS
  - GRIMES CANYON AQUIFER
  - WATER WELL
  - OIL WELL
  - APPROXIMATE LEVEL OF WATER IN WELLS

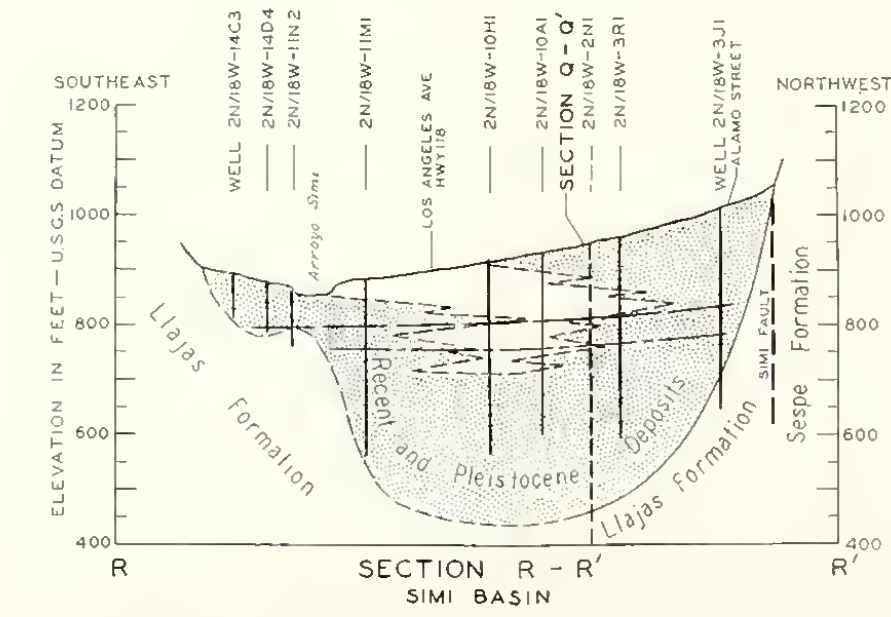
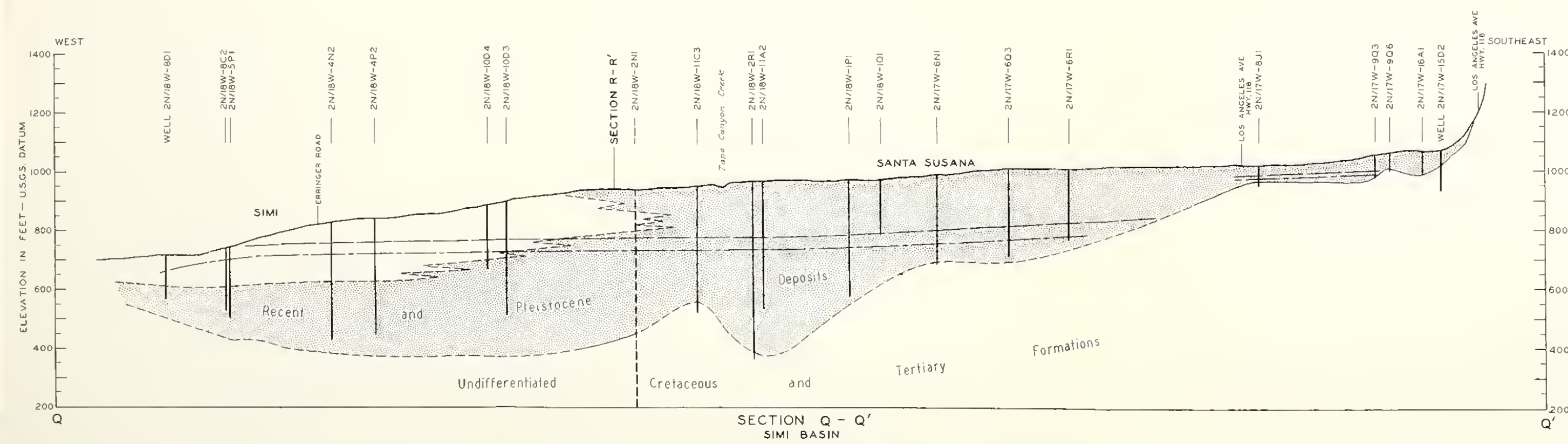
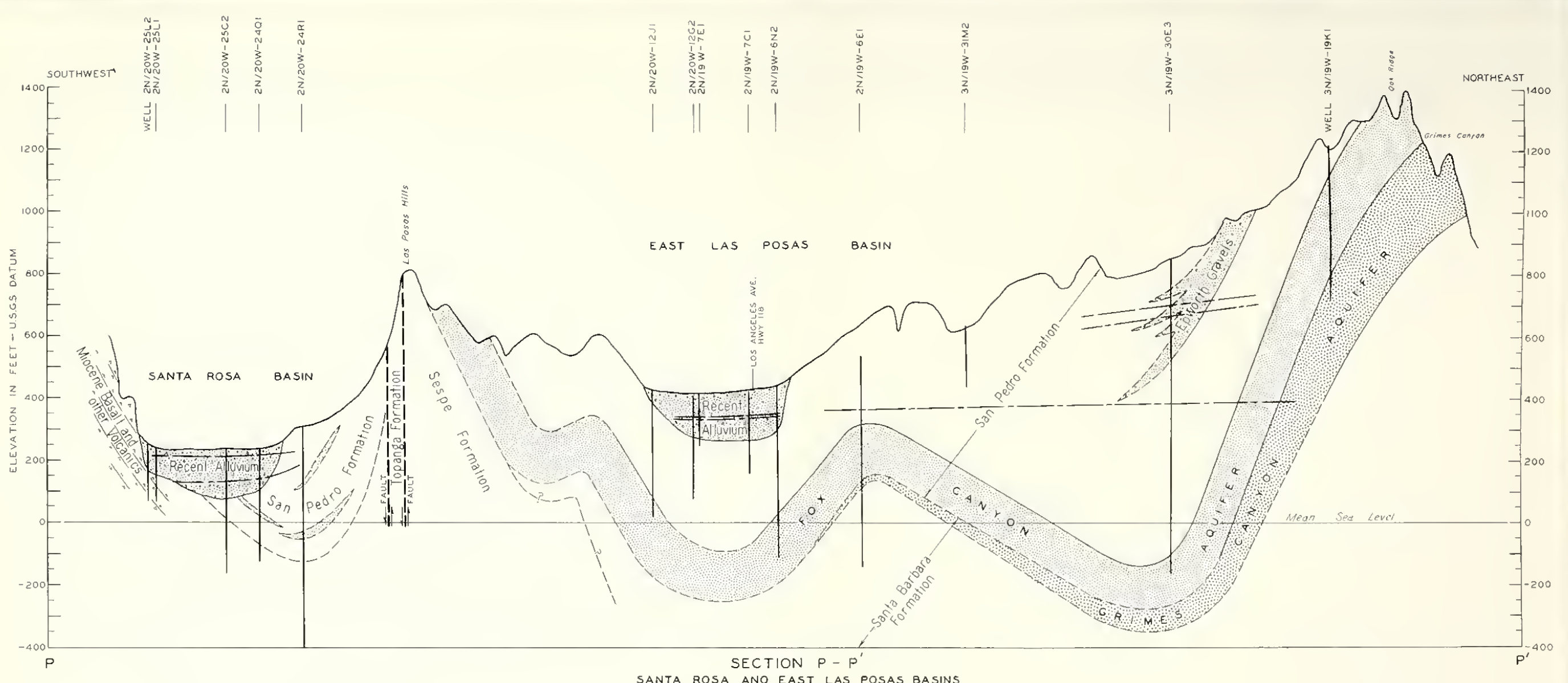
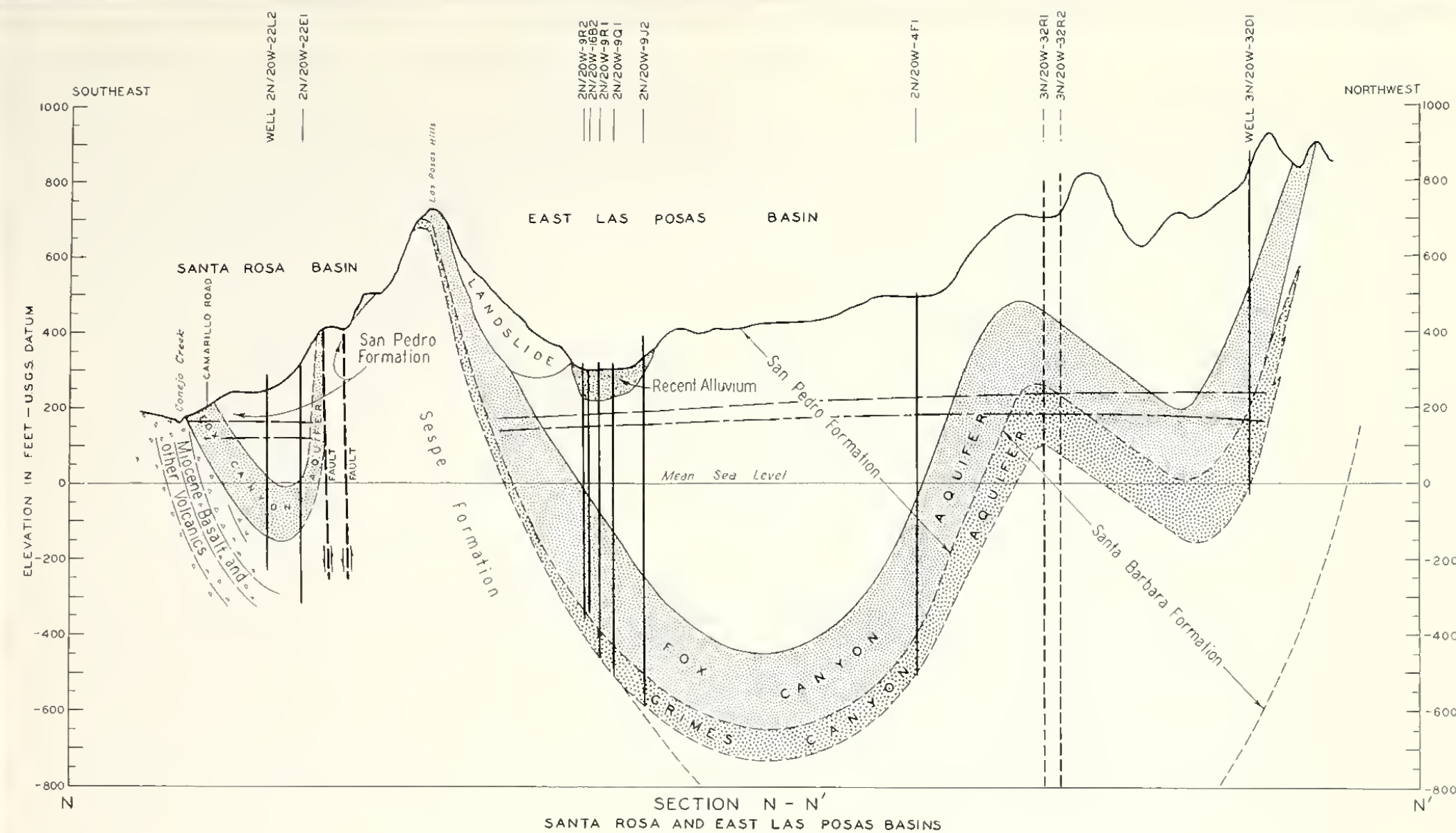
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**GEOLOGIC SECTIONS  
K-K', L-L' AND M-M'**  
1953

HORIZONTAL SCALE: 0 3000 6000 9000 FEET

NOTE: PLAN OF SECTIONS SHOWN ON PLATE 11







**LEGEND**

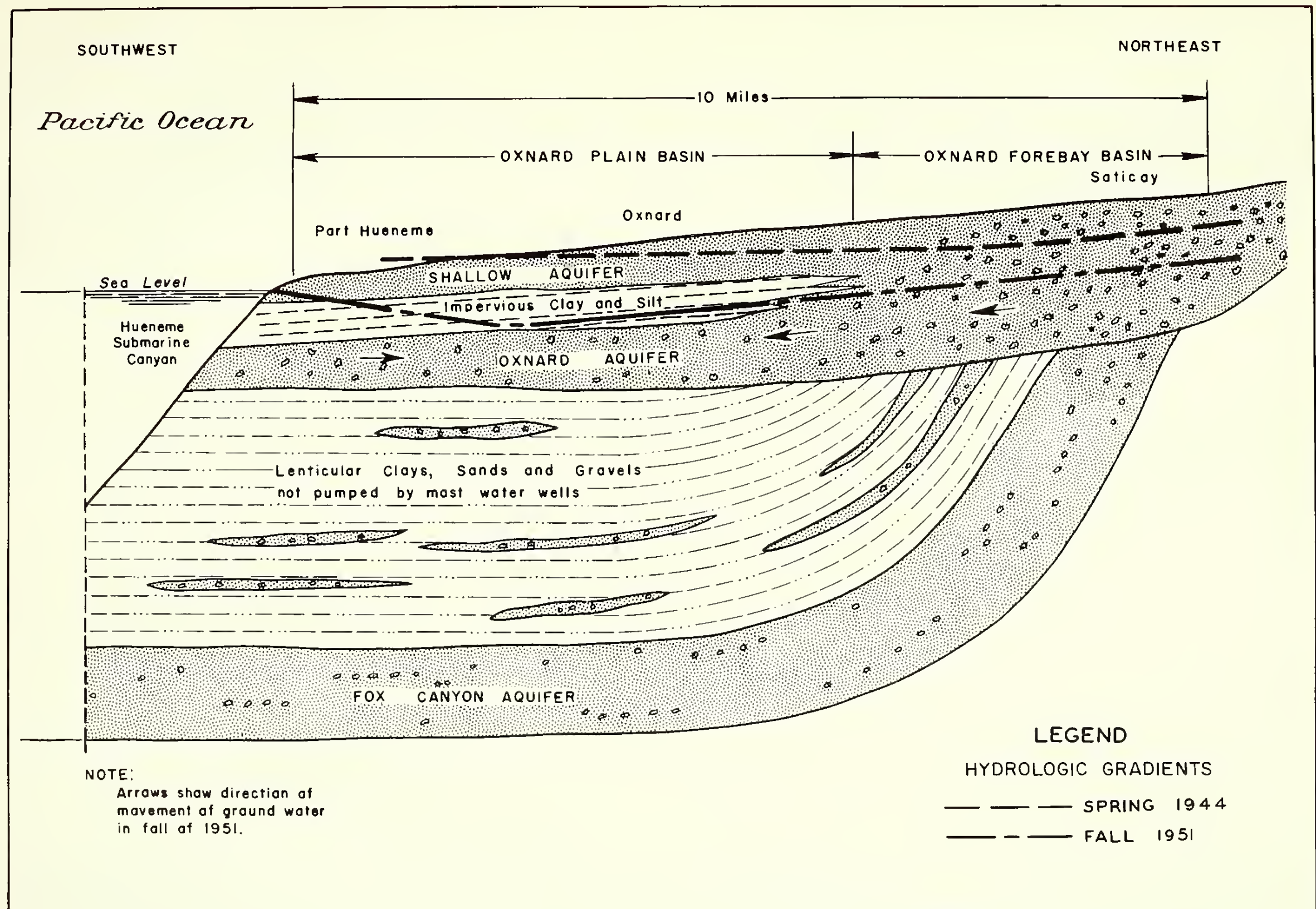
- DEPOSITS OF LOW PERMEABILITY
- RECENT AND UPPER PLEISTOCENE DEPOSITS
- FOX CANYON AQUIFER AND UNDIFFERENTIATED PLEISTOCENE DEPOSITS
- GRIMES CANYON AQUIFER
- WATER WELL
- OIL WELL
- APPROXIMATE LEVEL OF WATER IN WELLS (Spring 1925, Fall 1951)

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

**GEOLOGIC SECTIONS  
N-N', P-P', Q-Q' AND R-R'  
1953**

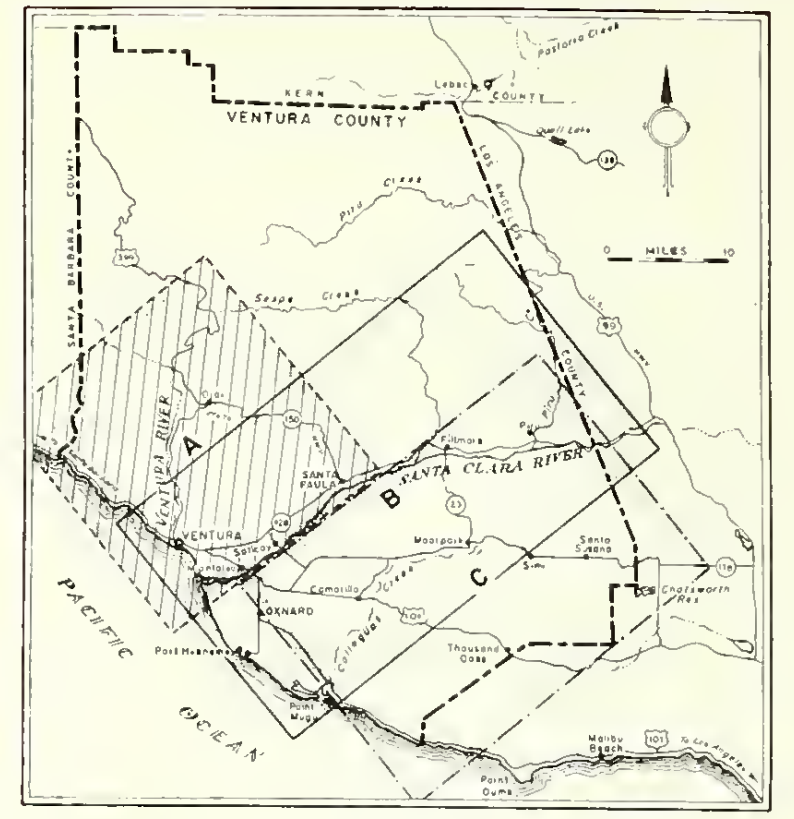
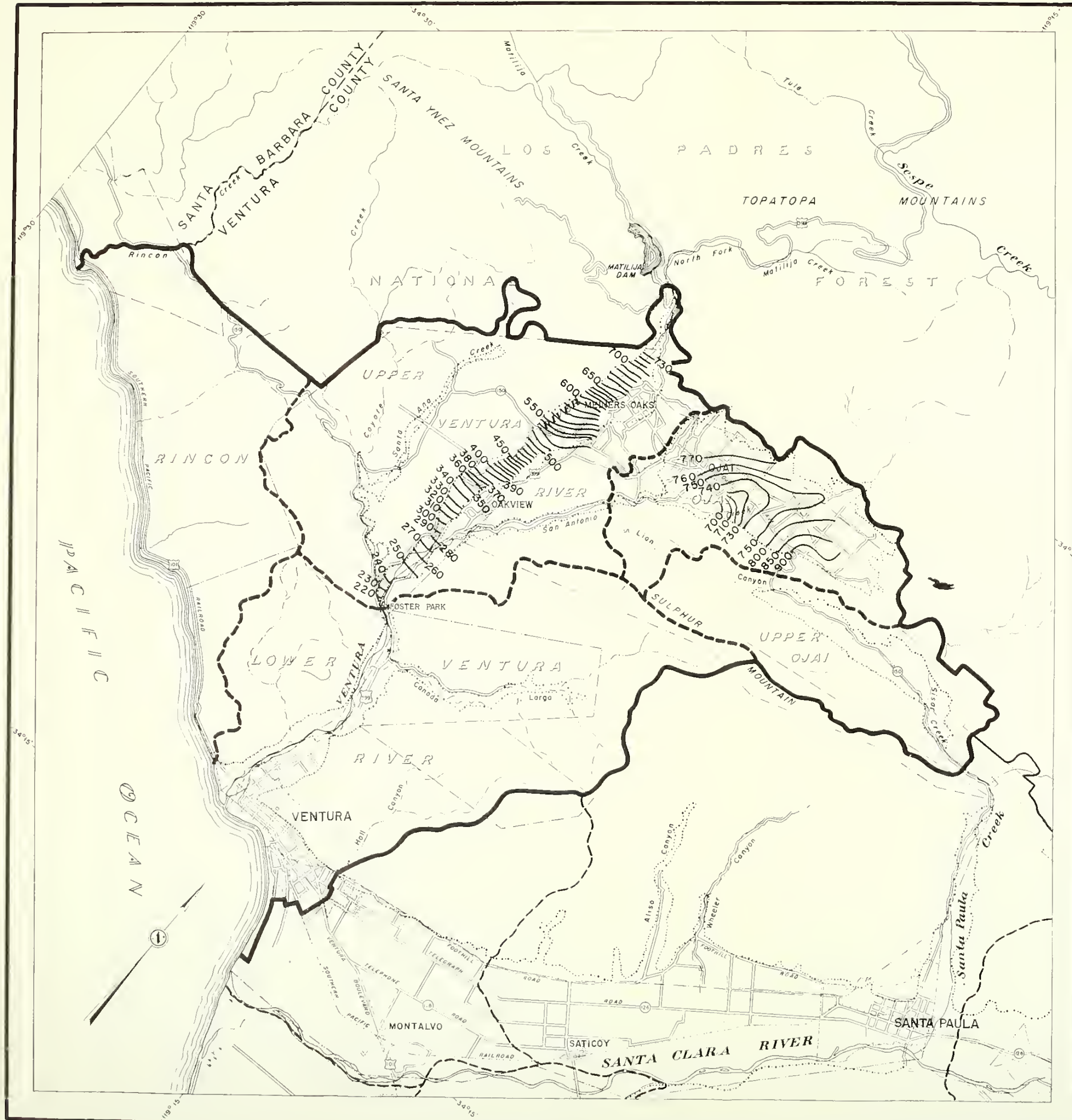
HORIZONTAL SCALE: 2000 0 2000 4000 6000 FEET





STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
DIAGRAMMATIC SKETCH OF  
OXNARD FOREBAY AND OXNARD PLAIN BASINS



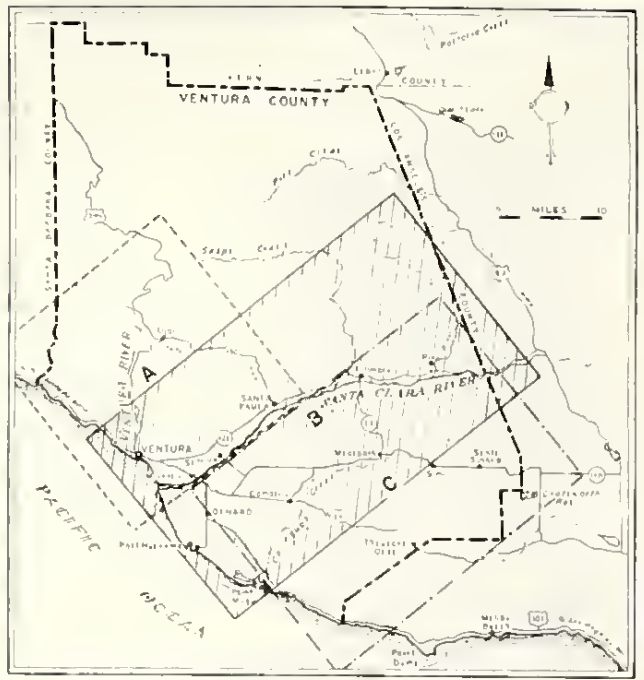


KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - OJAI NAME OF SUBUNIT
  - 20 LINES OF EQUAL ELEVATION OF GROUND WATER

STATE OF CALIFORNIA  
 DEPARTMENT OF PUBLIC WORKS  
 DIVISION OF WATER RESOURCES  
 VENTURA COUNTY INVESTIGATION  
 VENTURA HYDROLOGIC UNIT  
 LINES OF EQUAL ELEVATION  
 OF  
 GROUND WATER  
 FALL OF 1936  
 Scale of miles

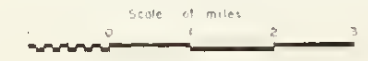




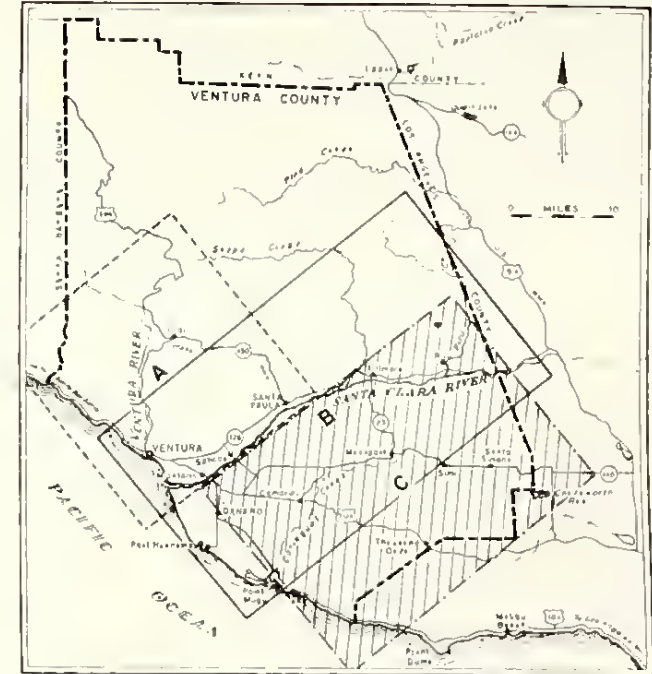
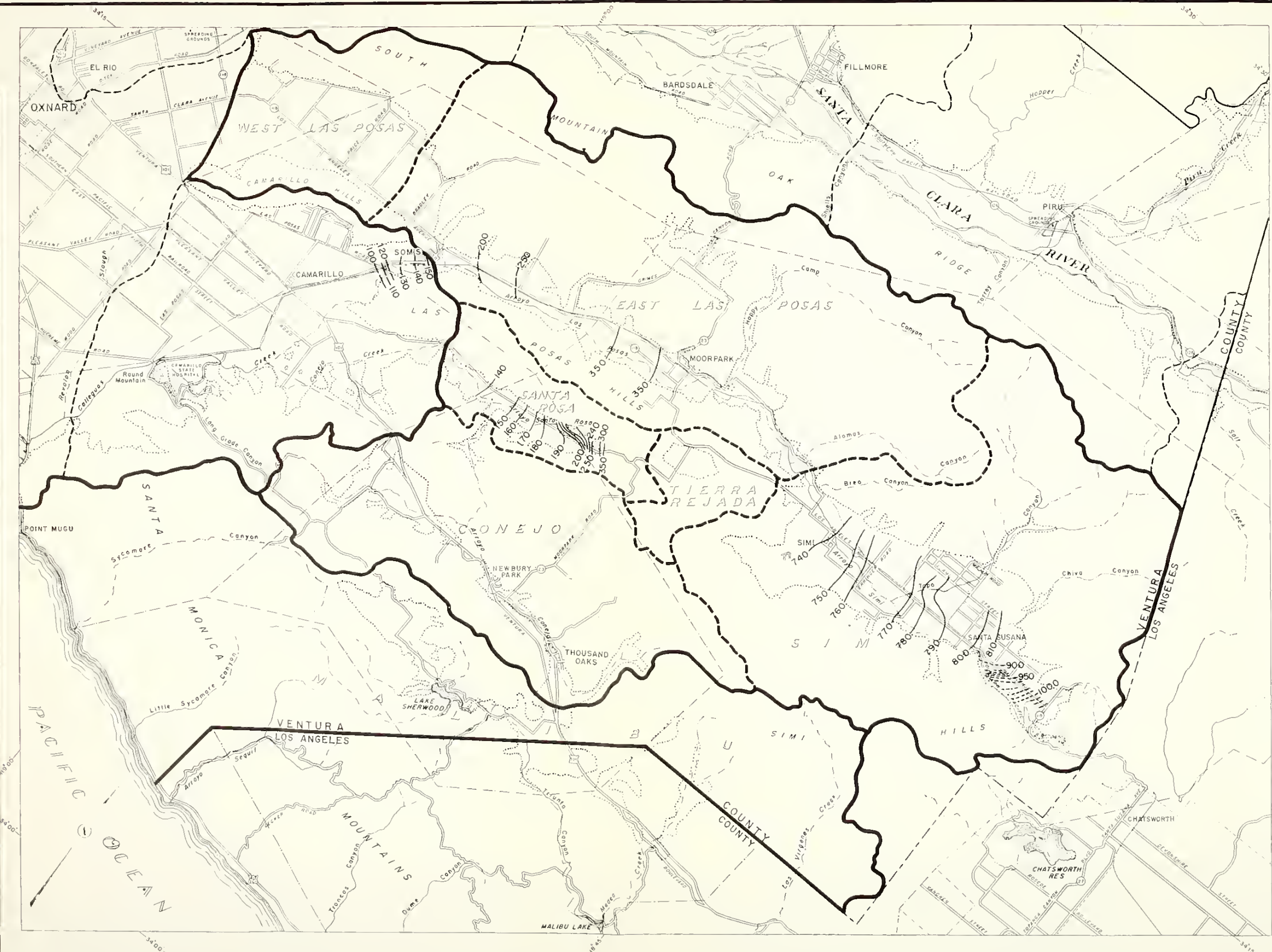
KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - - - SUBUNIT BOUNDARY
  - - - - - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - PIRU NAME OF SUBUNIT
  - 20 — LINES OF EQUAL ELEVATION OF GROUND WATER
  - - - 20 - - - LINES OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER
  - ▨▨▨▨ AREA WITH GROUND WATER ELEVATION BELOW SEA LEVEL

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
SANTA CLARA RIVER HYDROLOGIC UNIT  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
FALL OF 1936





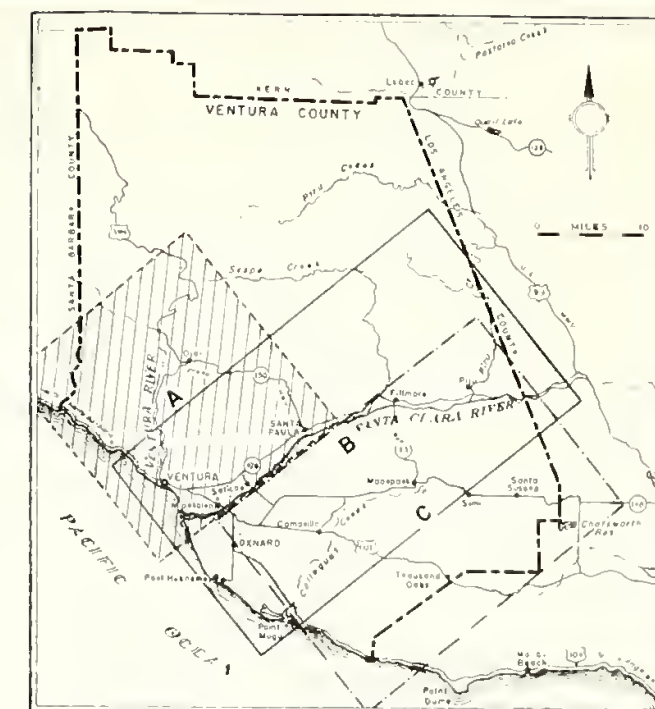


KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF HYDROLOGIC UNIT OR SUBUNIT
  - 20' LINES OF EQUAL ELEVATION OF GROUND WATER
  - 20' LINES OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER
  - 900' LINES OF EQUAL ELEVATION OF GROUND WATER IN OLDER ROCKS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
FALL OF 1936  
Scale of miles  
0 1 2 3





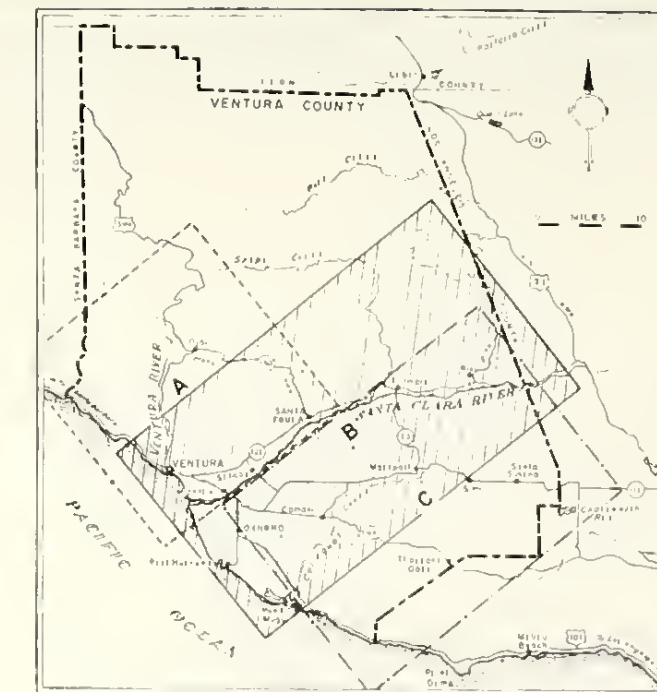
KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - - - SUBUNIT BOUNDARY
  - ..... APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - OJAI NAME OF SUBUNIT
  - 20 — LINES OF EQUAL ELEVATION OF GROUND WATER

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
VENTURA HYDROLOGIC UNIT  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
SPRING OF 1944

Scale of miles  
0 1 2 3





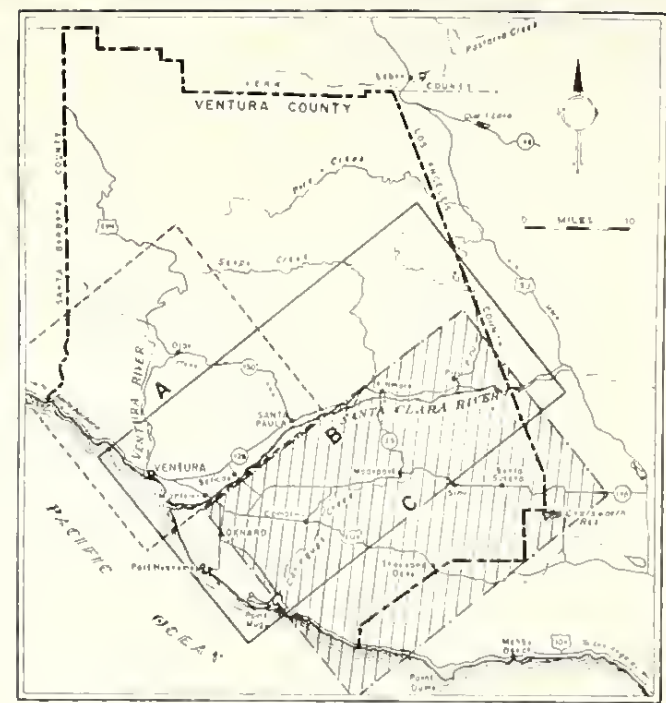
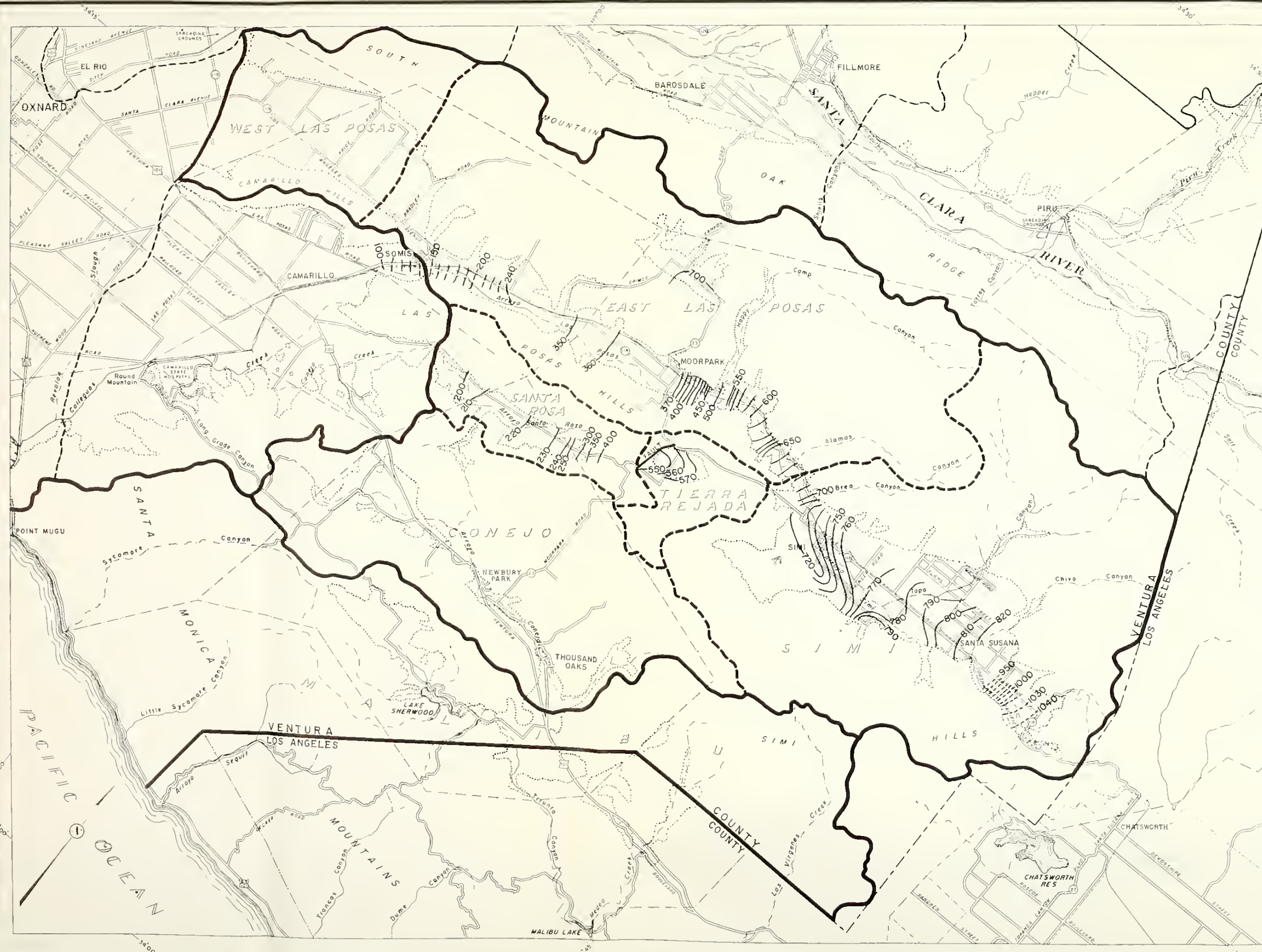
KEY MAP

- LEGEND**
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF SUBUNIT
  - LINES OF EQUAL ELEVATION OF GROUND WATER
  - LINES OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER
  - AREA WITH PIEZOMETRIC SURFACE ABOVE GROUND SURFACE

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
SANTA CLARA RIVER HYDROLOGIC UNIT  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
SPRING OF 1944





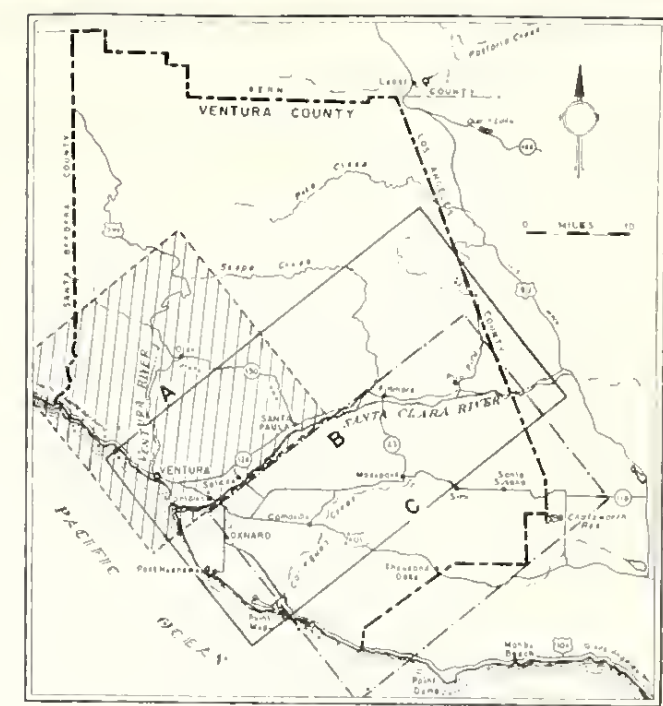


KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - SIMI NAME OF SUBUNIT
  - 20 LINES OF EQUAL ELEVATION OF GROUND WATER
  - 20 LINES OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER
  - 950 LINES OF EQUAL ELEVATION OF GROUND WATER IN OLDER ROCKS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
SPRING OF 1944  
Scale of miles





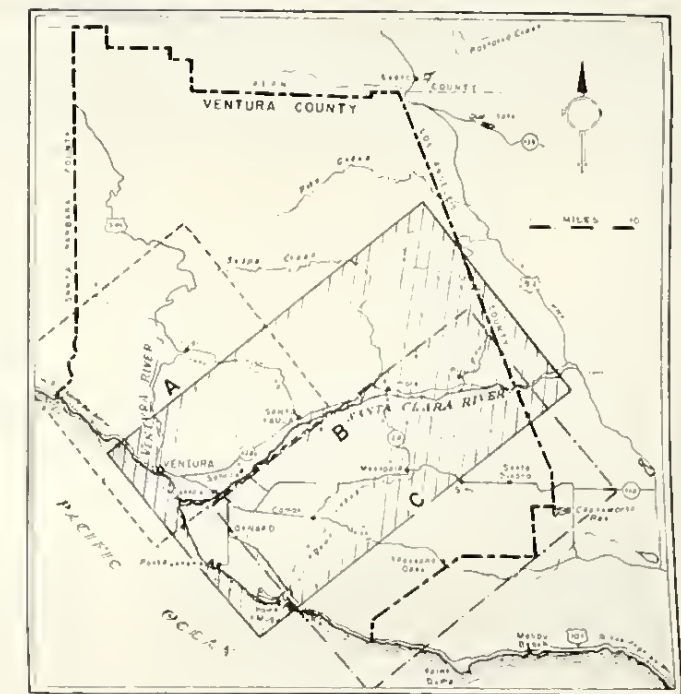
KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF SUBUNIT
  - LINES OF EQUAL ELEVATION OF GROUND WATER

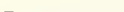
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
VENTURA HYDROLOGIC UNIT  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
FALL OF 1951

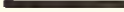


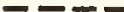





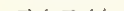
LEGEND


 HYDROLOGIC UNIT BOUNDARY


 SUBUNIT BOUNDARY


 APPROXIMATE BOUNDARY OF VALLEY FLOOR


 NAME OF SUBUNIT


 LINES OF EQUAL ELEVATION OF GROUND WATER

 LINES OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER

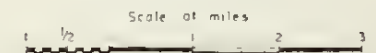
 AREA WITH GROUND WATER ELEVATION BELOW SEA LEVEL

 AREAL EXTENT OF LANDWARD GRADIENT IN PIEZOMETRIC SURFACE OF PUMPING AQUIFERS

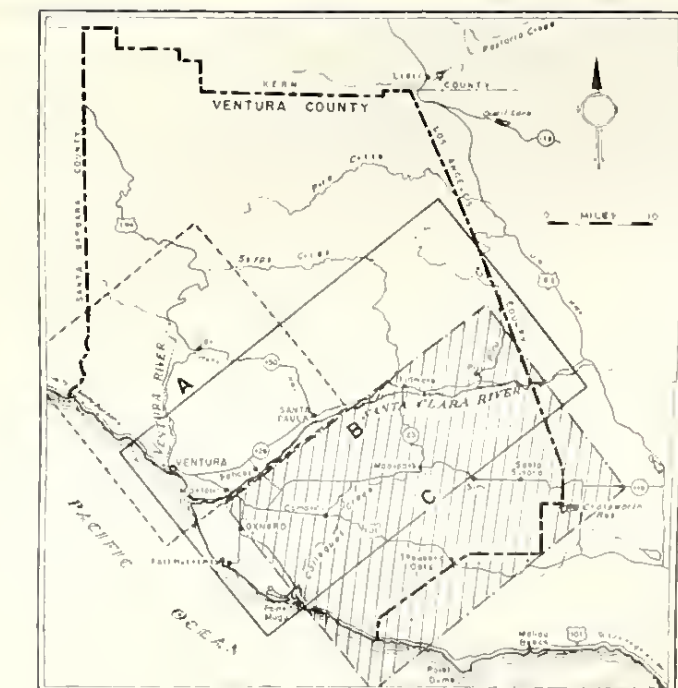
 PROBABLE EXTENT OF SEA WATER INTRUSION IN OXNARD AQUIFER



STATE OF CALIFORNIA  
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VENTURA COUNTY INVESTIGATION  
SANTA CLARA RIVER HYDROLOGIC UNIT  
LINES OF EQUAL ELEVATION  
OF  
GROUND WATER  
FALL OF 1951







KEY MAP

LEGEND

- |                |   |
|----------------|---|
| —————          | HYDROLOGIC UNIT BOUNDARY                                      |
| - - - - -      | SUBUNIT BOUNDARY  |
| .....          | APPROXIMATE BOUNDARY OF VALLEY FLOOR                          |
| <i>S 1 M 1</i> | NAME OF HYDROLOGIC UNIT OR SUBUNIT                            |
| —20—           | LINE OF EQUAL ELEVATION OF GROUND WATER                       |
| —20—           | LINE OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER |
| ---900---      | LINE OF EQUAL ELEVATION OF GROUND WATER IN OLDER ROCKS        |

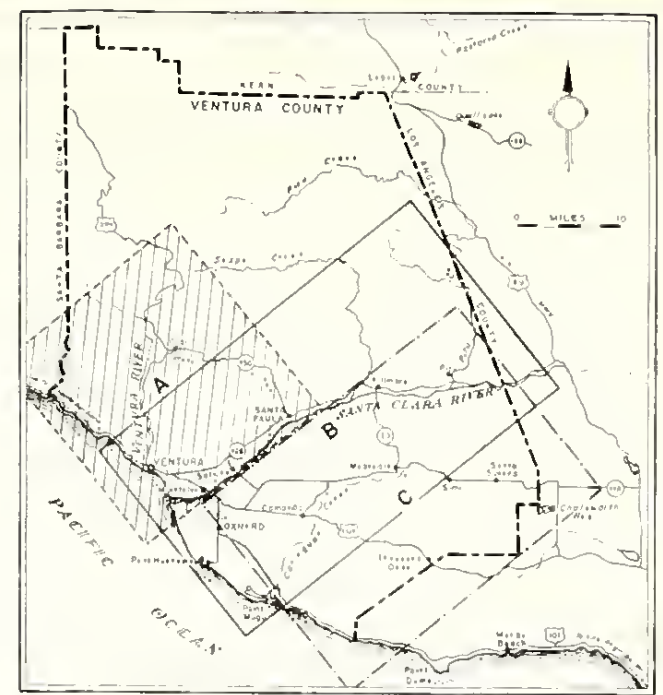
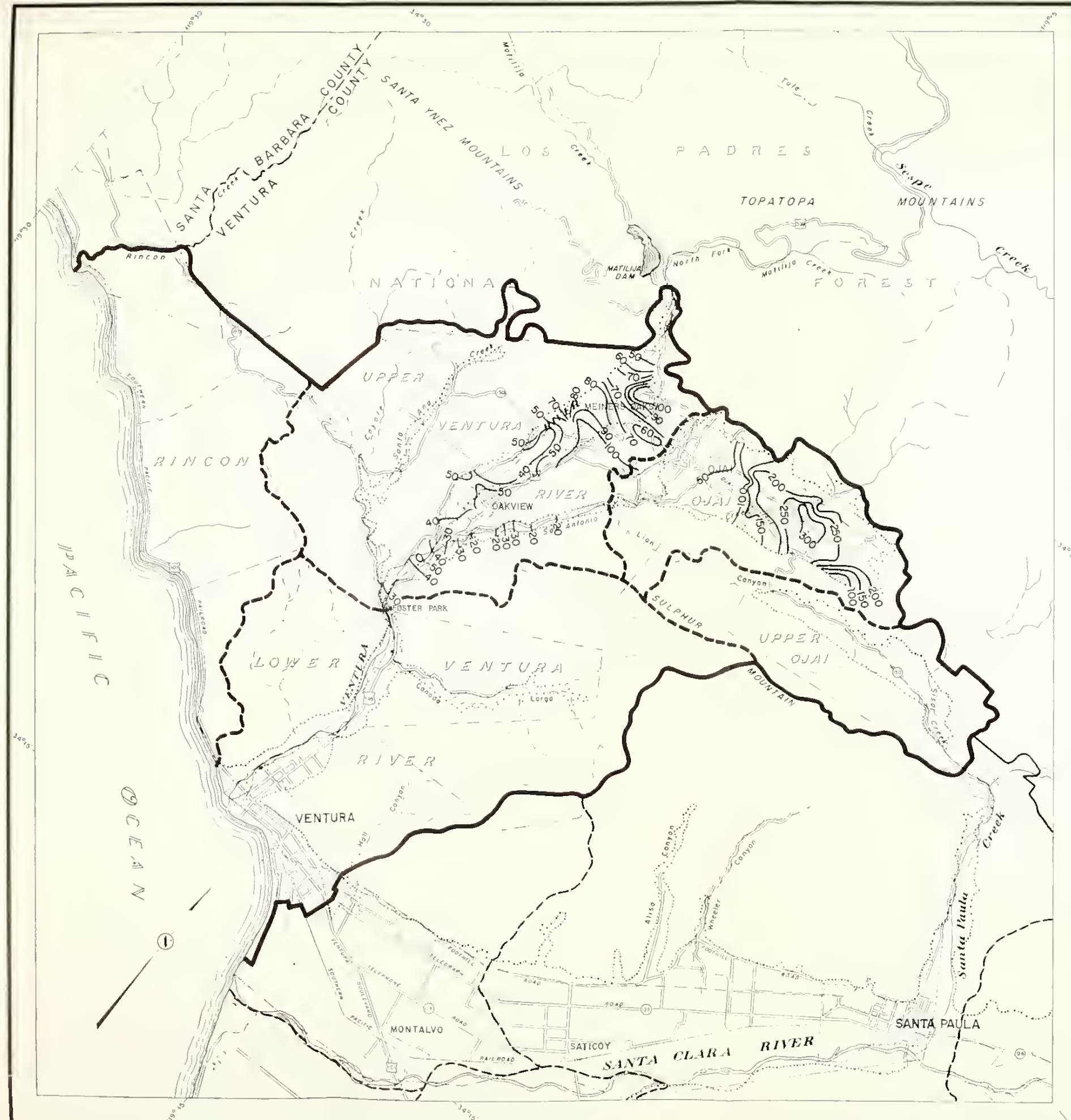
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS

LINES OF EQUAL ELEVATION  
 OF  
 GROUND WATER  
 FALL OF 1951

Scale of miles

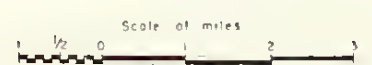




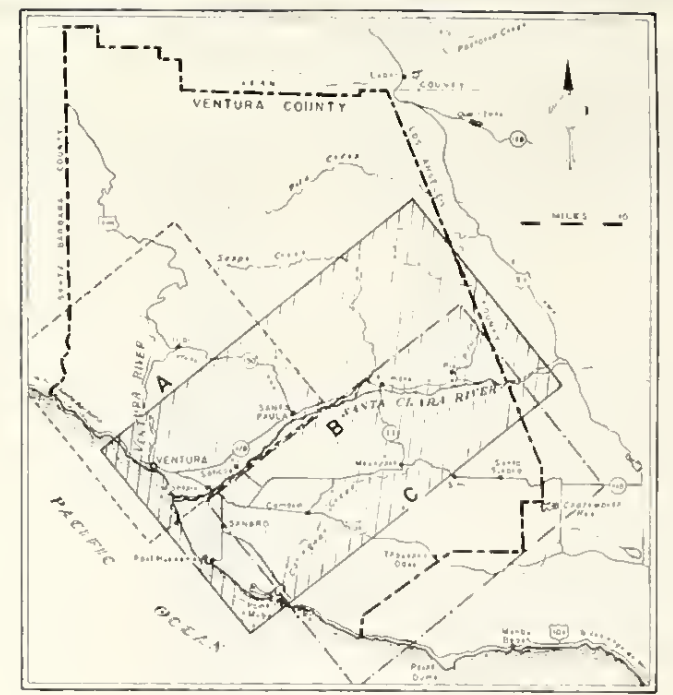


- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - OJAI NAME OF SUBUNIT
  - 20 LINES OF EQUAL DEPTH TO GROUND WATER

STATE OF CALIFORNIA  
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VENTURA COUNTY INVESTIGATION  
VENTURA HYDROLOGIC UNIT  
LINES OF EQUAL DEPTH  
TO  
GROUND WATER  
FALL OF 1951



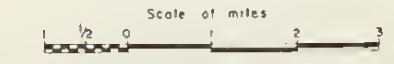




KEY MAP

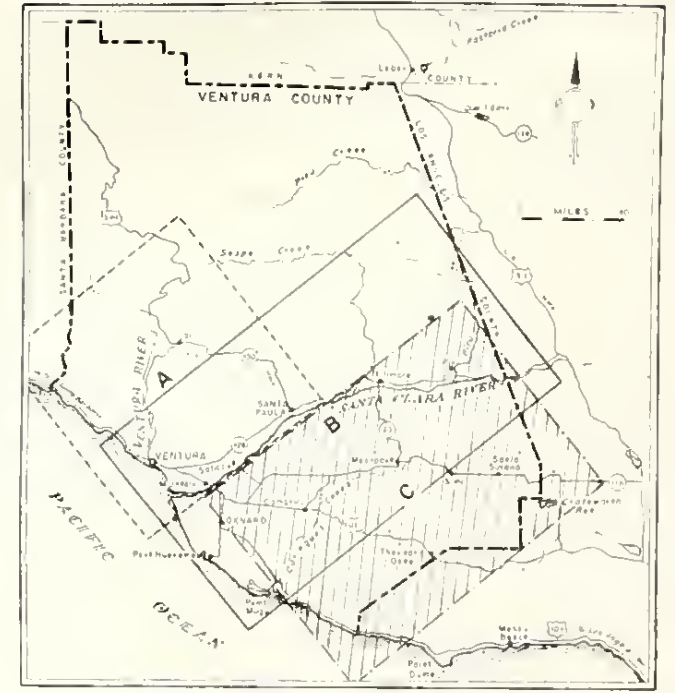
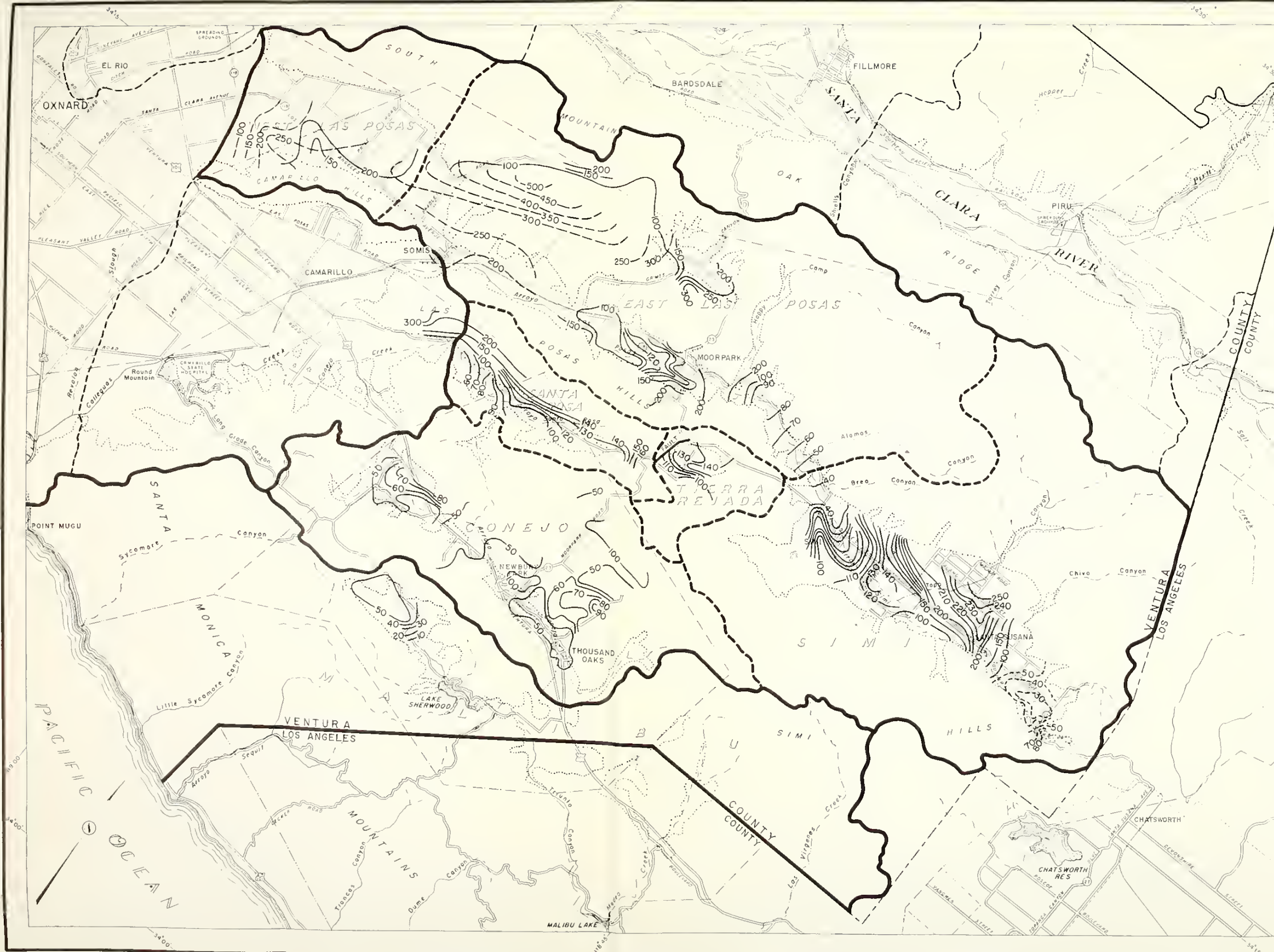
- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF SUBUNIT
  - 20 — LINES OF EQUAL DEPTH TO GROUND WATER
  - 100 — LINES OF EQUAL DEPTH TO GROUND WATER IN FOX CANYON AQUIFER

STATE OF CALIFORNIA  
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DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
SANTA CLARA RIVER HYDROLOGIC UNIT  
LINES OF EQUAL DEPTH  
TO  
GROUND WATER  
FALL OF 1951









KEY MAP

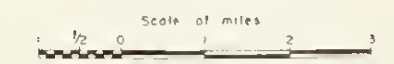
- LEGEND**
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - S I M I NAME OF HYDROLOGIC UNIT OR SUBUNIT
  - LINES OF EQUAL DEPTH TO GROUND WATER
  - LINES OF EQUAL DEPTH TO GROUND WATER IN FOX CANYON AQUIFER
  - LINES OF EQUAL DEPTH TO GROUND WATER IN OLDER ROCKS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES

VENTURA COUNTY INVESTIGATION

CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS

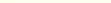
**LINES OF EQUAL DEPTH**  
TO  
**GROUND WATER**  
FALL OF 1951

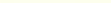


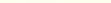


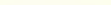


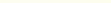
LEGEND


 HYDROLOGIC UNIT BOUNDARY

 SUBUNIT BOUNDARY

 APPROXIMATE BOUNDARY OF VALLEY FLOOR

 NAME OF SUBUNIT

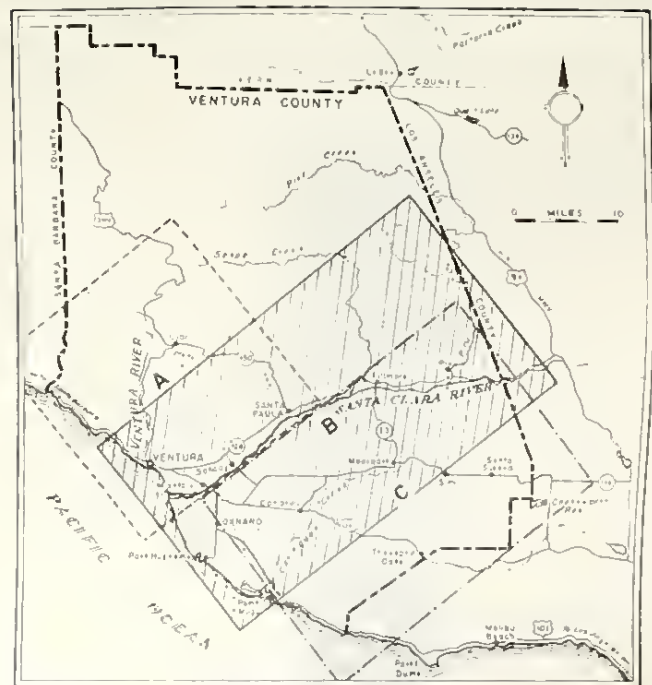
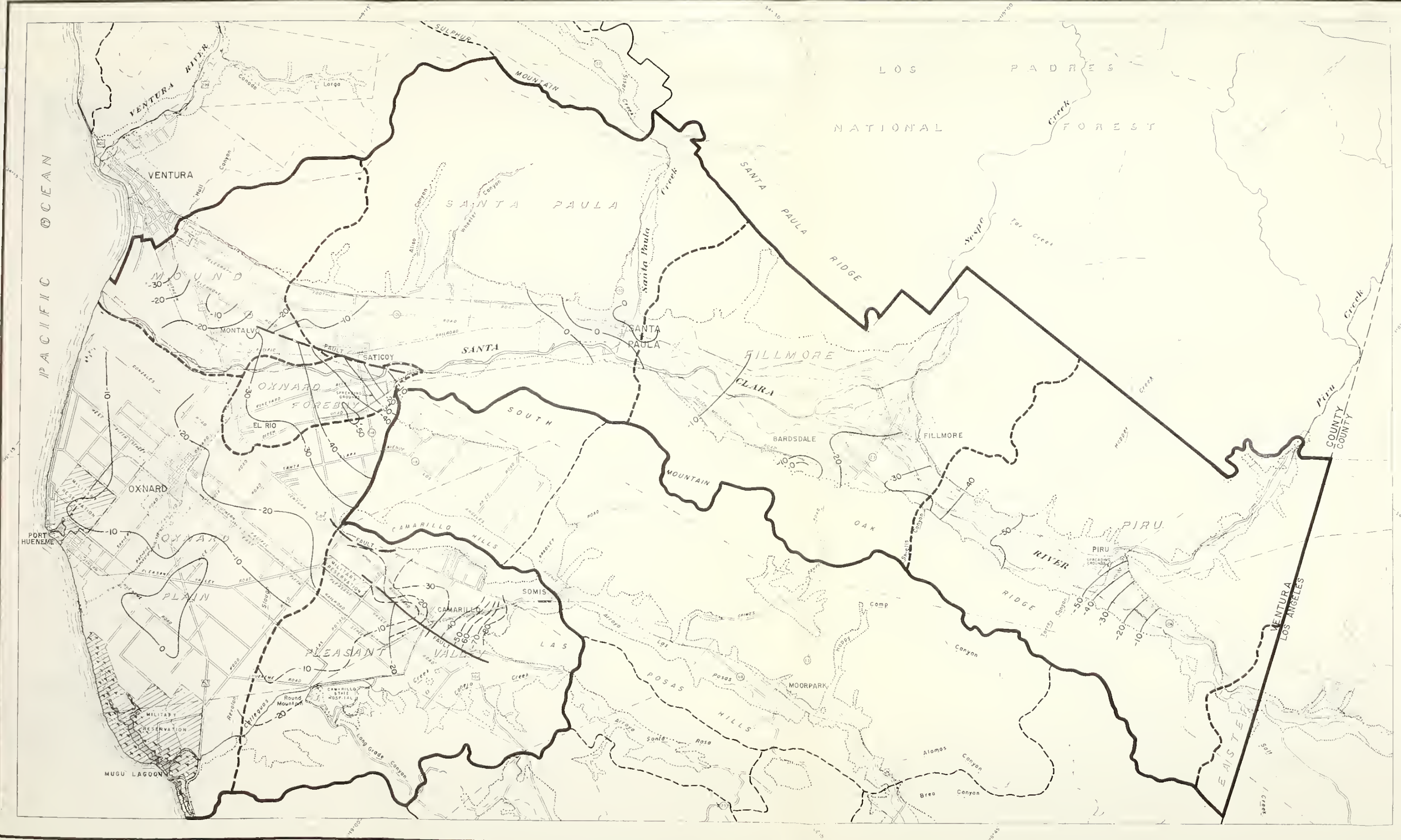
 LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION



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DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
VENTURA HYDROLOGIC UNIT  
LINES OF EQUAL CHANGE  
IN  
GROUND WATER ELEVATION  
FALL OF 1936 TO FALL OF 1951







KEY MAP

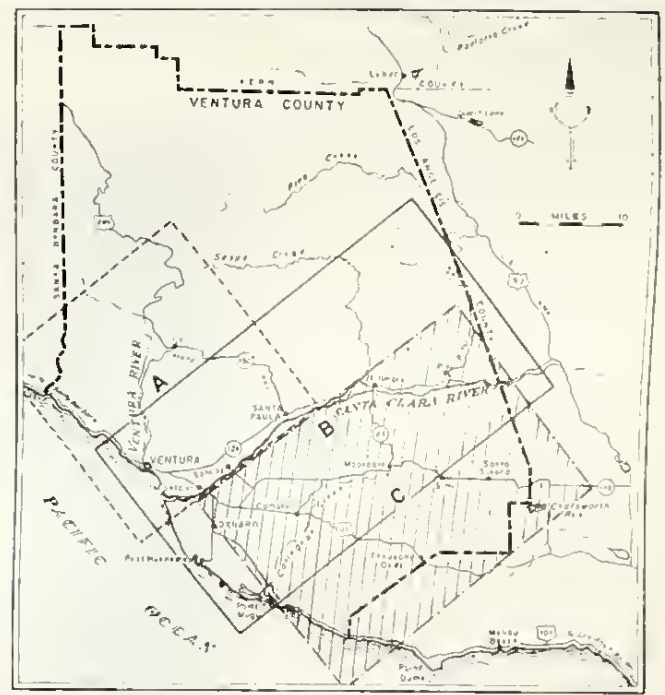
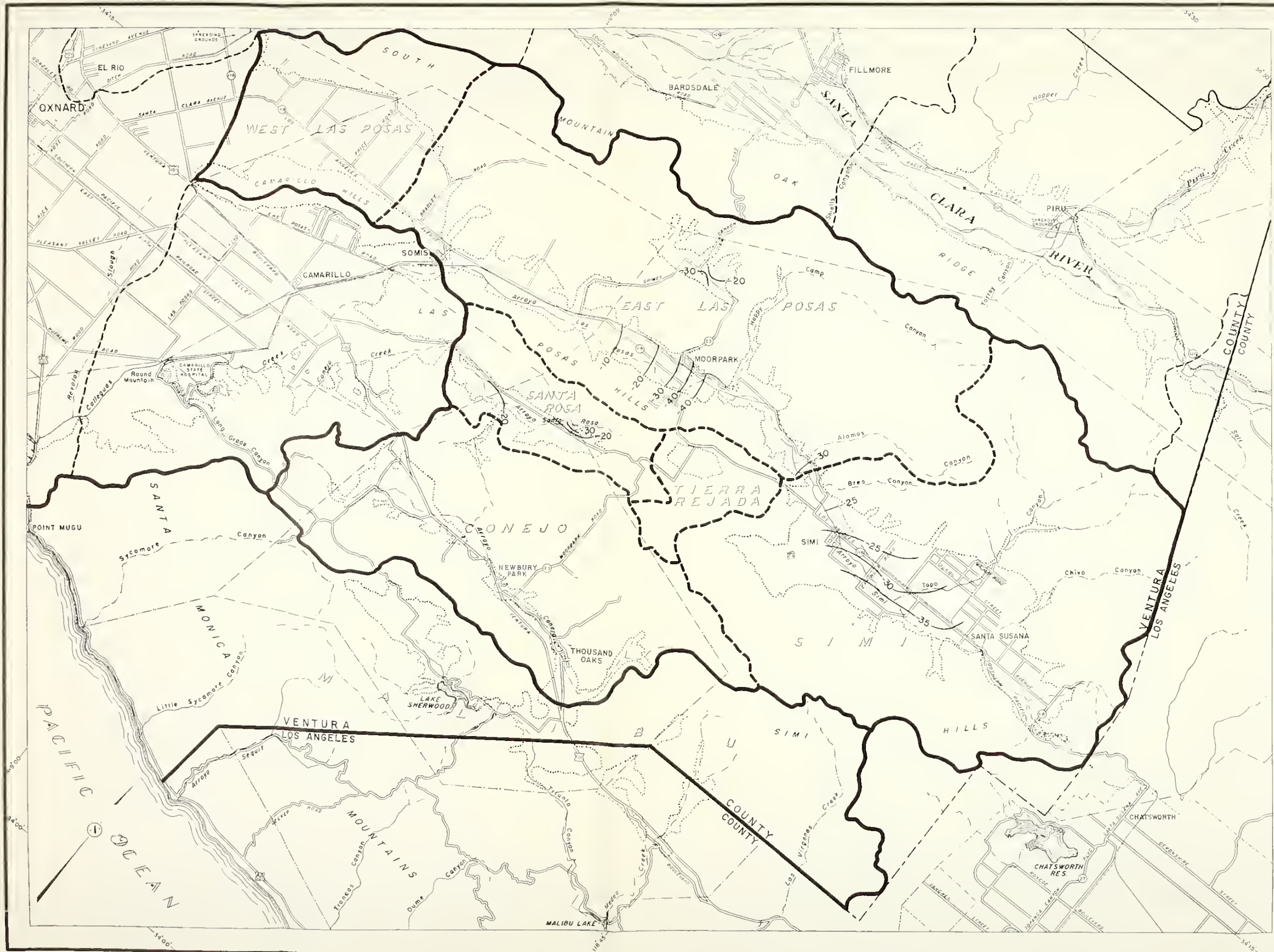
- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF SUBUNIT
  - LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION
  - LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION IN FOX CANYON AQUIFER

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DIVISION OF WATER RESOURCES

VENTURA COUNTY INVESTIGATION  
SANTA CLARA RIVER HYDROLOGIC UNIT  
LINES OF EQUAL CHANGE  
IN  
GROUND WATER ELEVATION  
FALL OF 1936 TO FALL OF 1951

Scale: 1 mile  
0 1 2 3



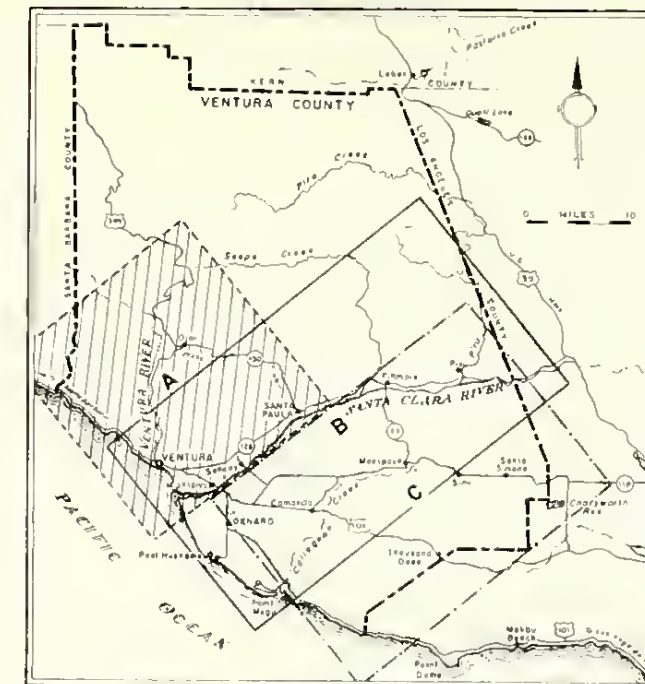


KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - NAME OF HYDROLOGIC UNIT OR SUBUNIT
  - 20
  - 30
  - 40
  - 50

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 VENTURA COUNTY INVESTIGATION  
 CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS  
 LINES OF EQUAL CHANGE  
 IN  
 GROUND WATER ELEVATION  
 FALL OF 1936 TO FALL OF 1951  
 Scale of miles  
 0 1 2 3

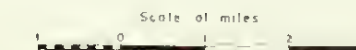




KEY MAP

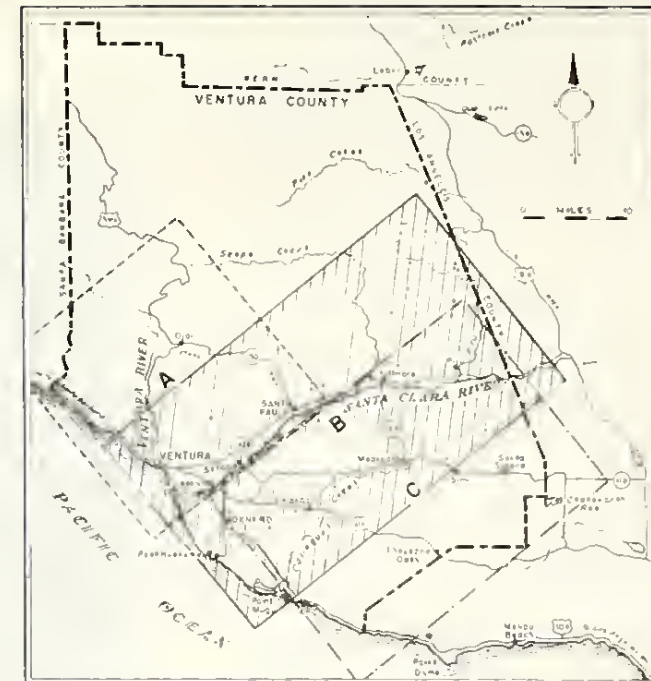
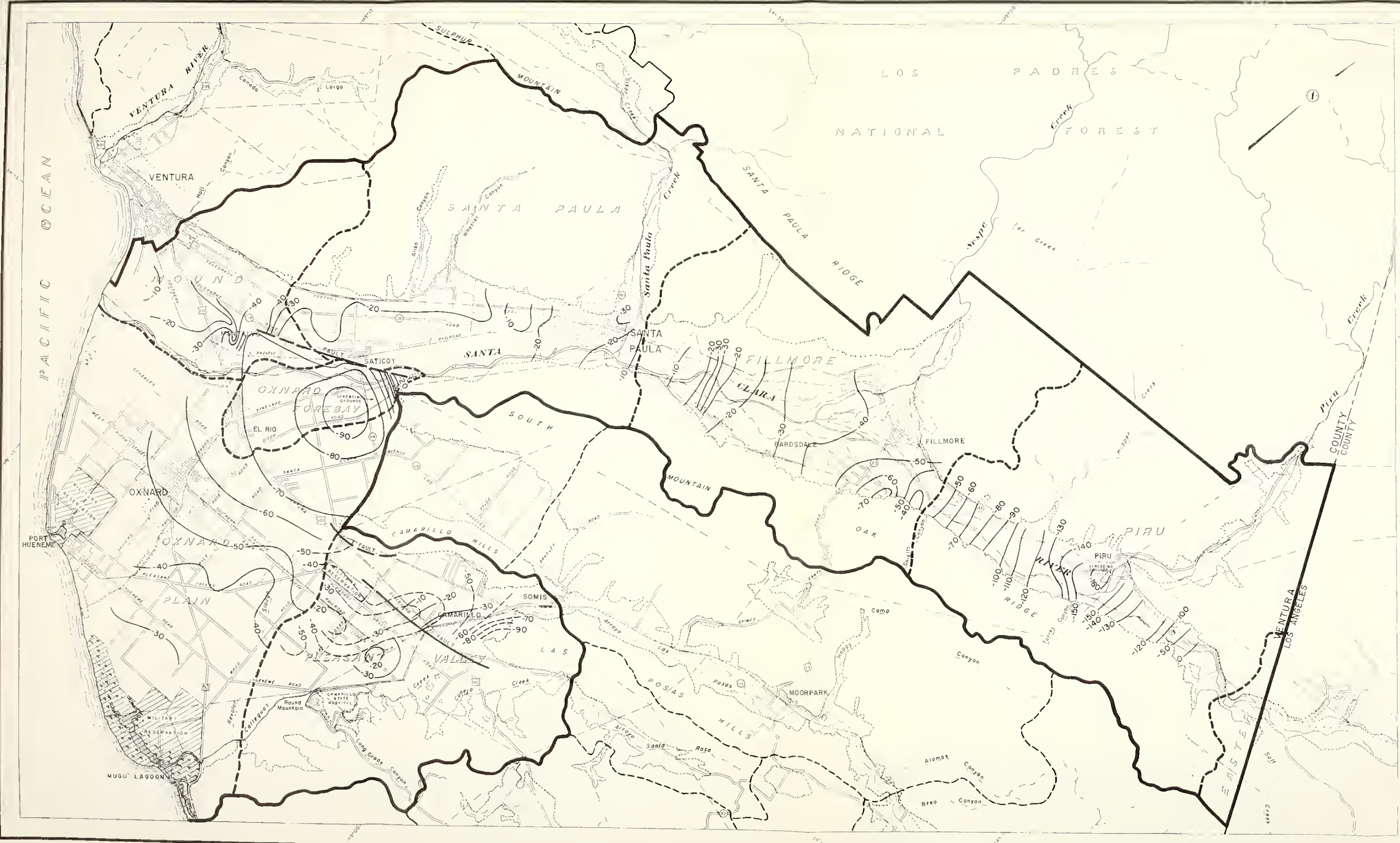
- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - OJAI NAME OF SUBUNIT
  - 20- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
VENTURA HYDROLOGIC UNIT  
LINES OF EQUAL CHANGE  
IN  
GROUND WATER ELEVATION  
SPRING OF 1944 TO FALL OF 1951









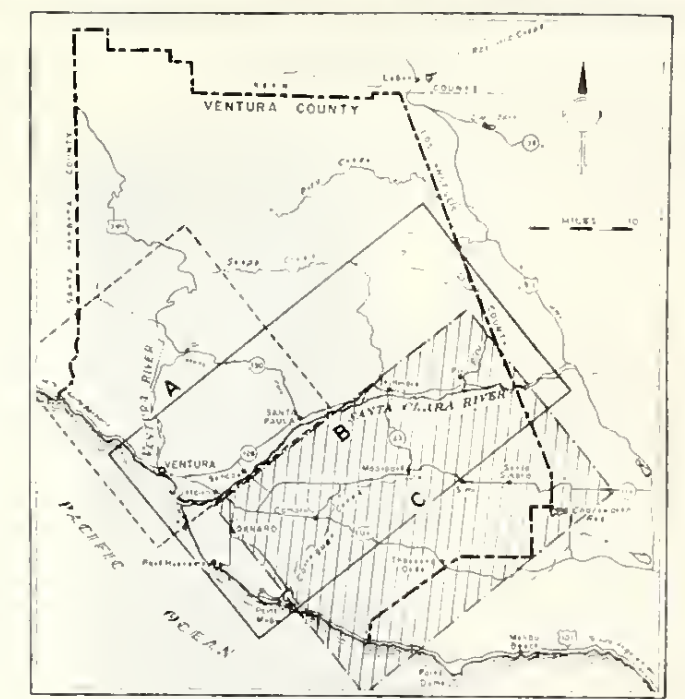
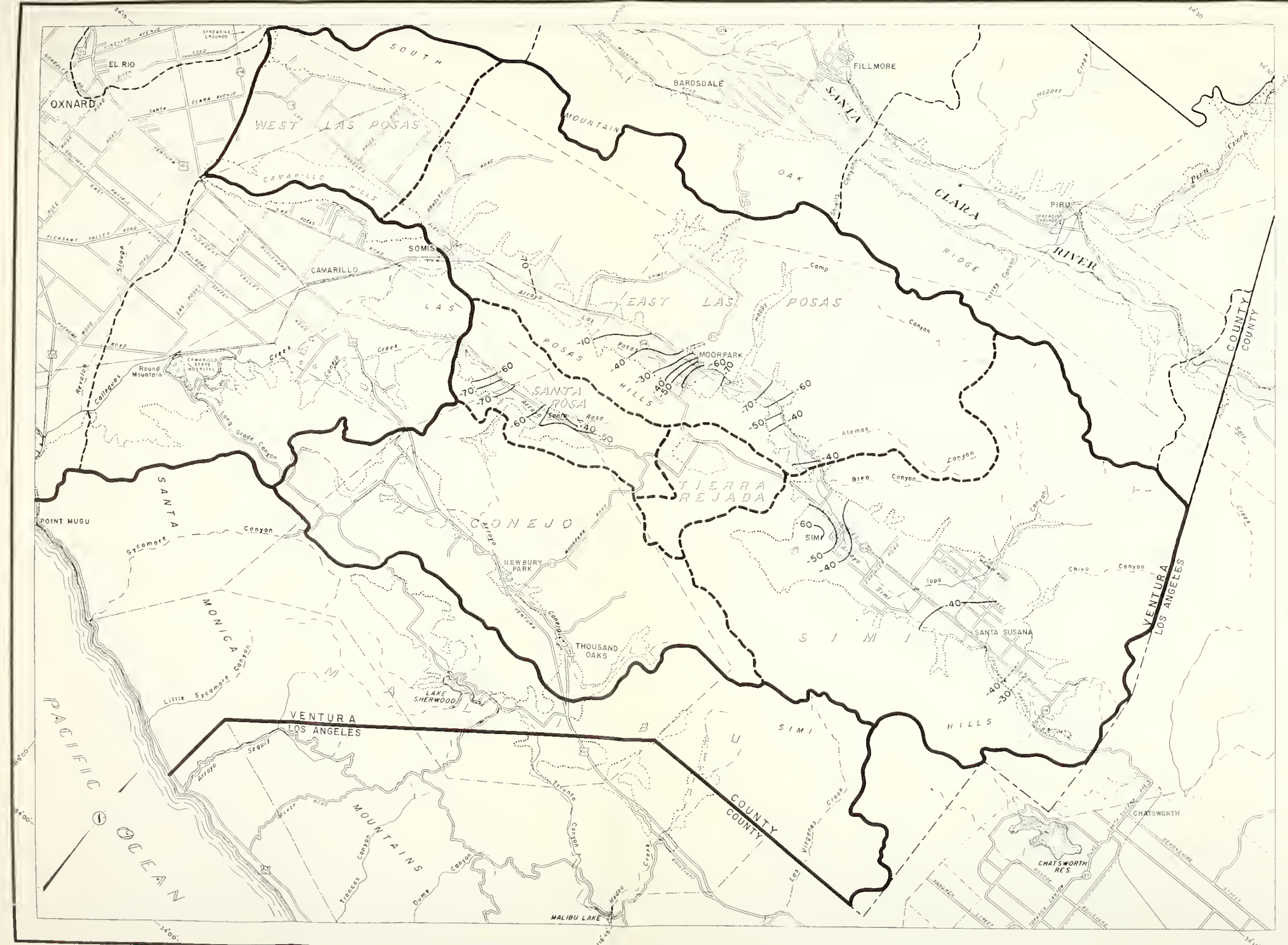
KEY MAP

——— HYDROLOGIC UNIT BOUNDARY  
 - - - - - SUBUNIT BOUNDARY  
 - - - - - APPROXIMATE BOUNDARY OF VALLEY FLOOR  
 PIRU NAME OF SUBUNIT  
 -20- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION  
 -20- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION IN FOX CANYON AQUIFER

STATE OF CALIFORNIA  
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 VENTURA COUNTY INVESTIGATION  
 SANTA CLARA RIVER HYDROLOGIC UNIT  
 LINES OF EQUAL CHANGE  
 IN  
 GROUND WATER ELEVATION  
 SPRING OF 1944 TO FALL OF 1951







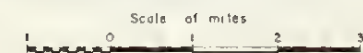
KEY MAP

- LEGEND**
- HYDROLOGIC UNIT BOUNDARY
  - - - SUBUNIT BOUNDARY
  - - - - - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - SIMI NAME OF SUBAREA
  - 20- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION
  - 20- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION IN FOX CANYON AQUIFER
  - 40- LINES OF EQUAL CHANGE IN GROUND WATER ELEVATION IN OLDER ROCKS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS

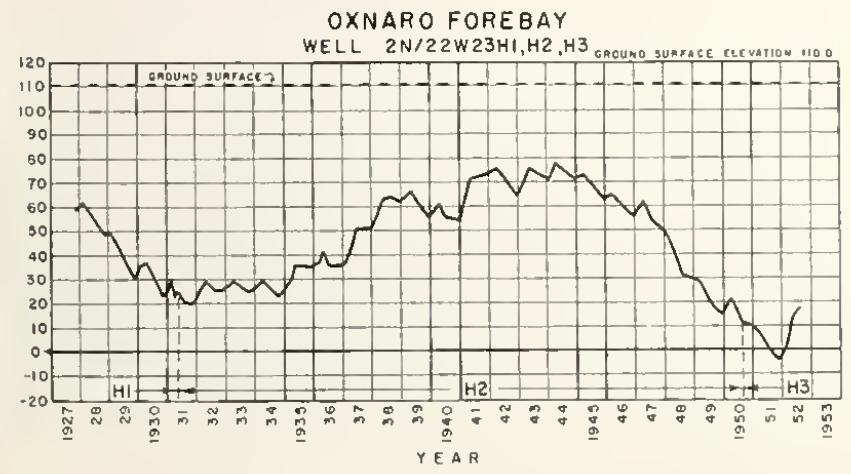
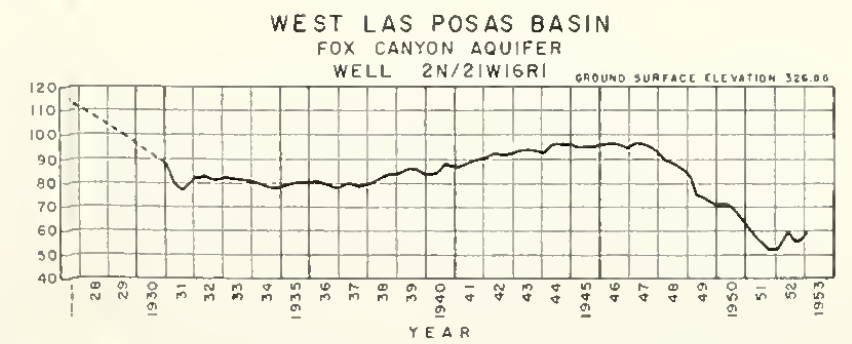
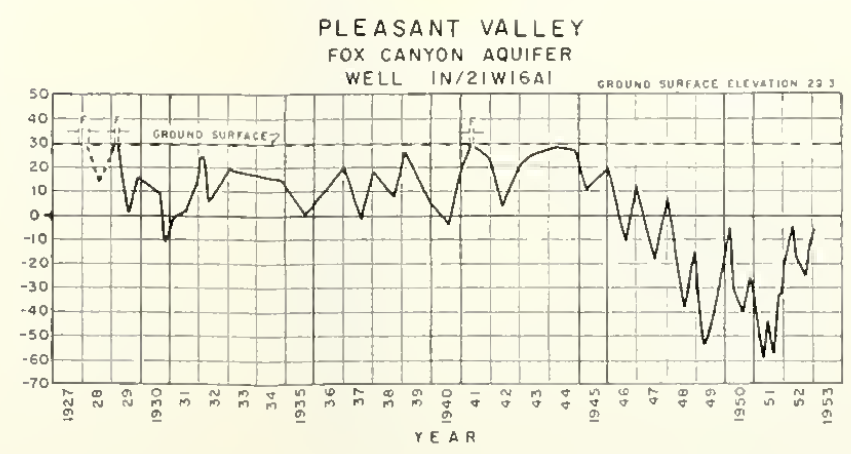
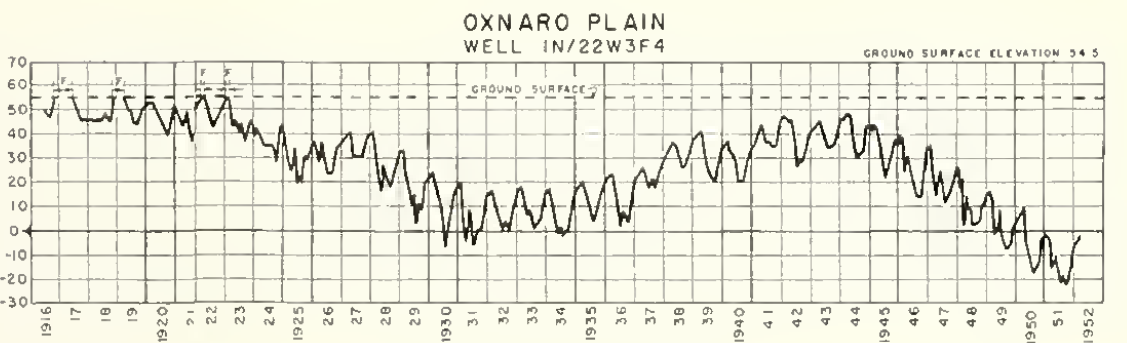
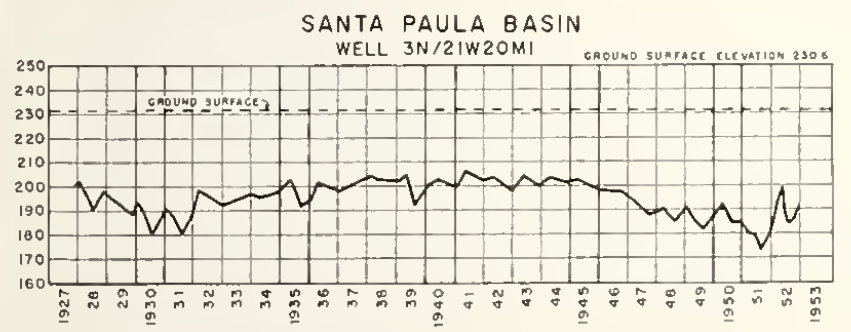
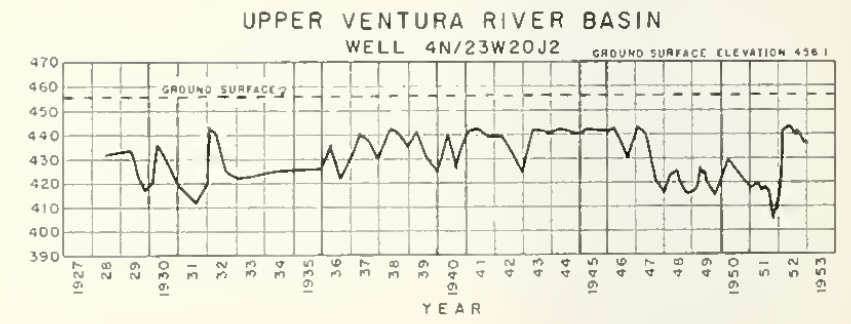
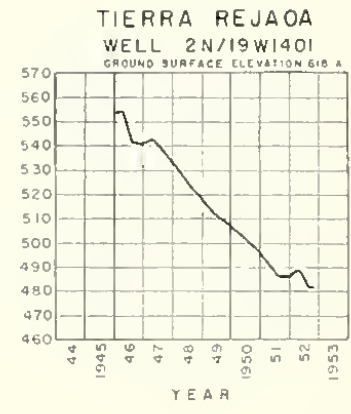
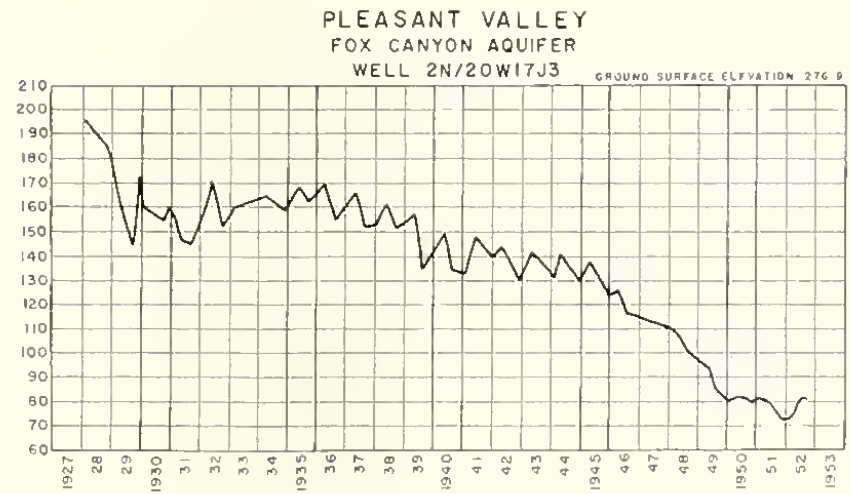
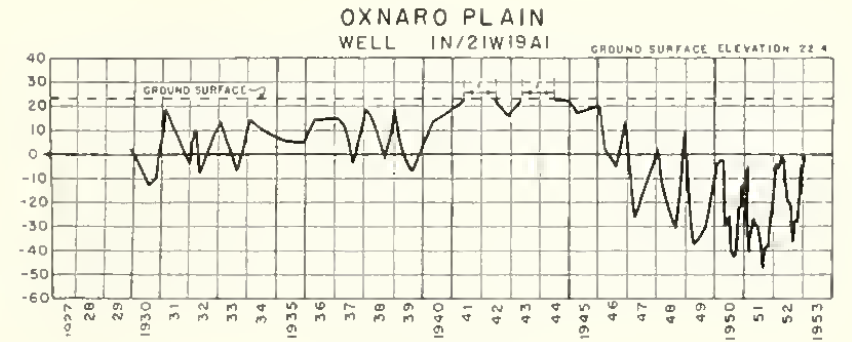
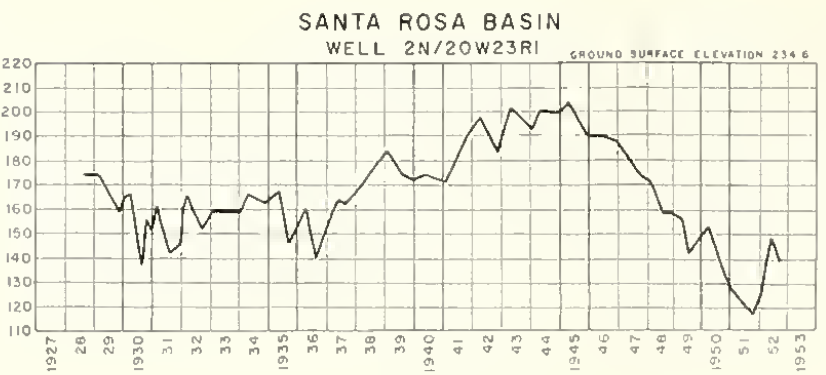
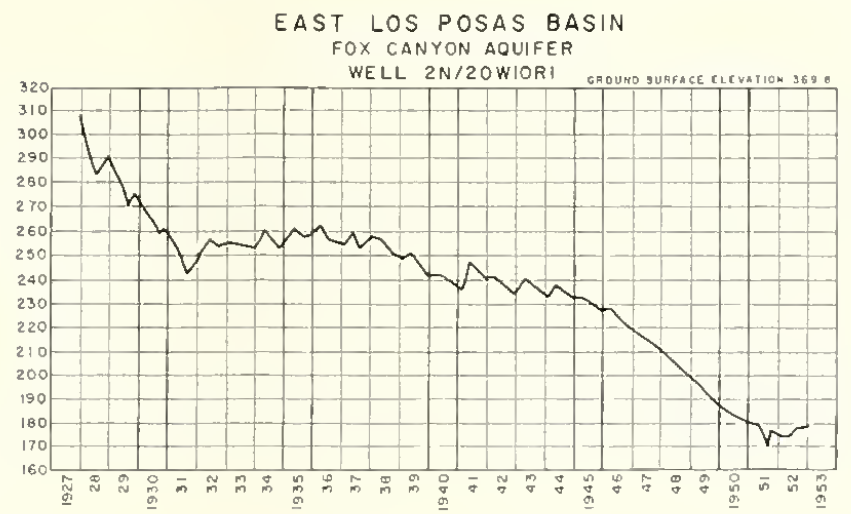
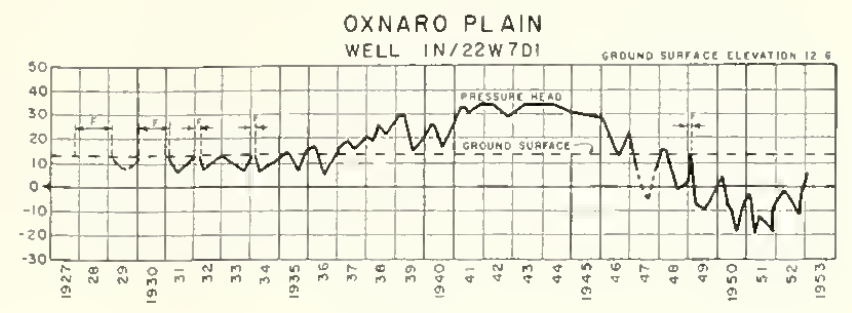
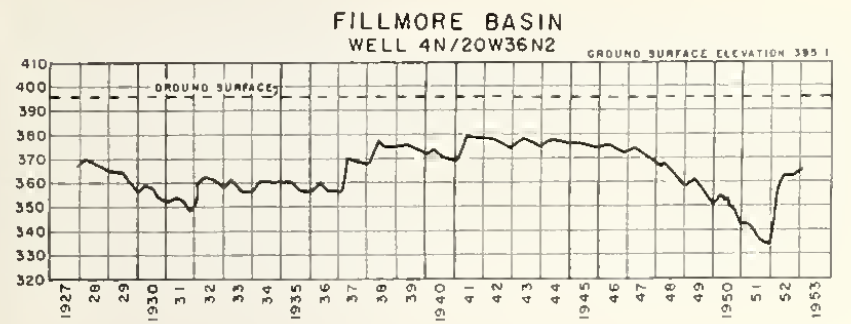
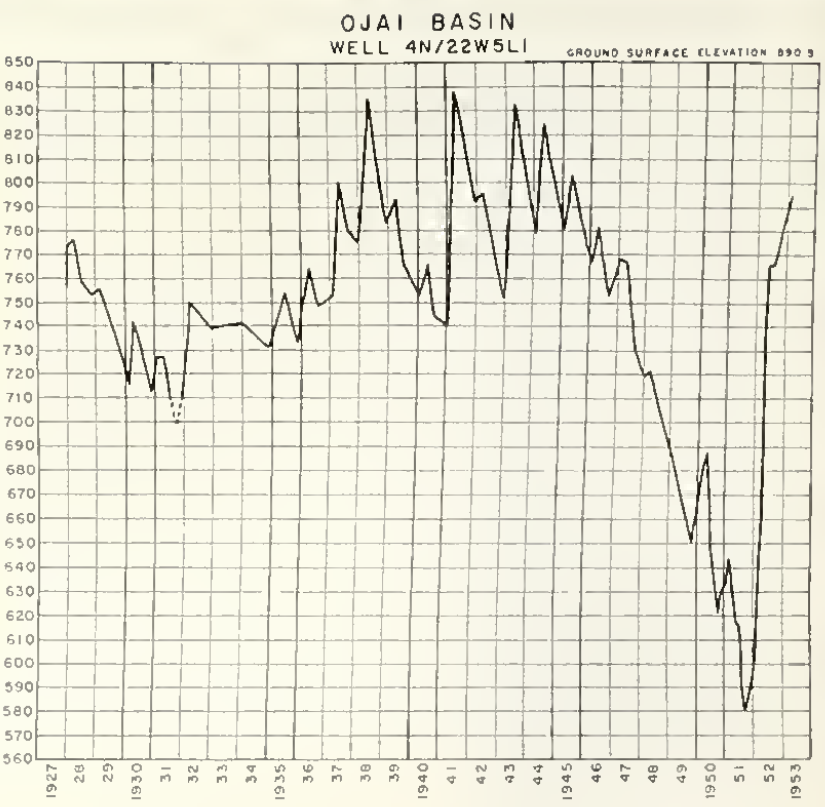
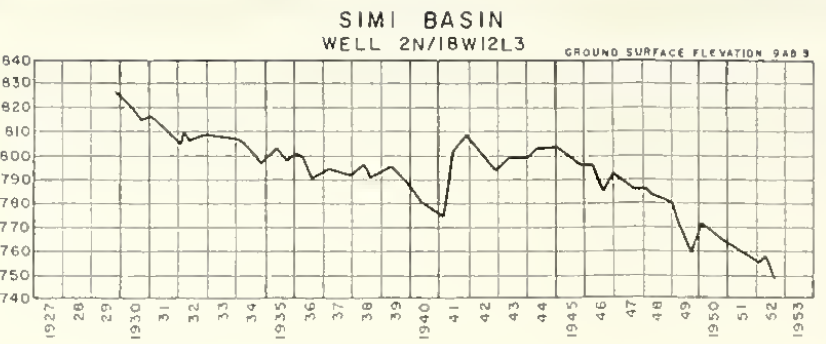
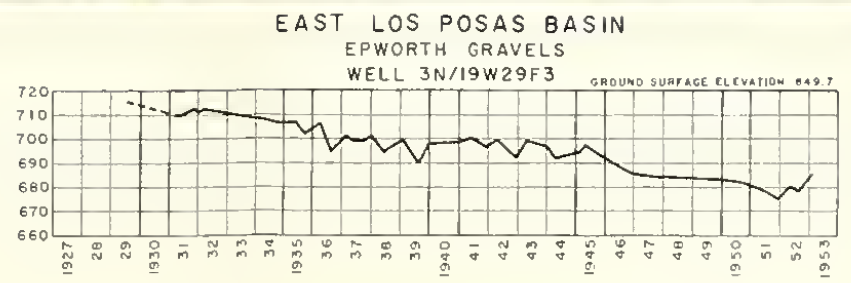
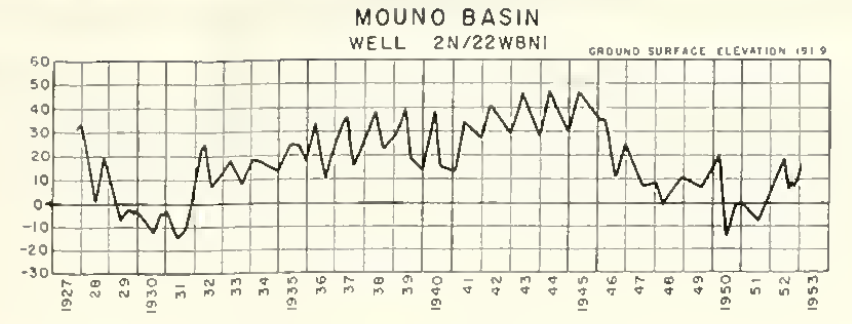
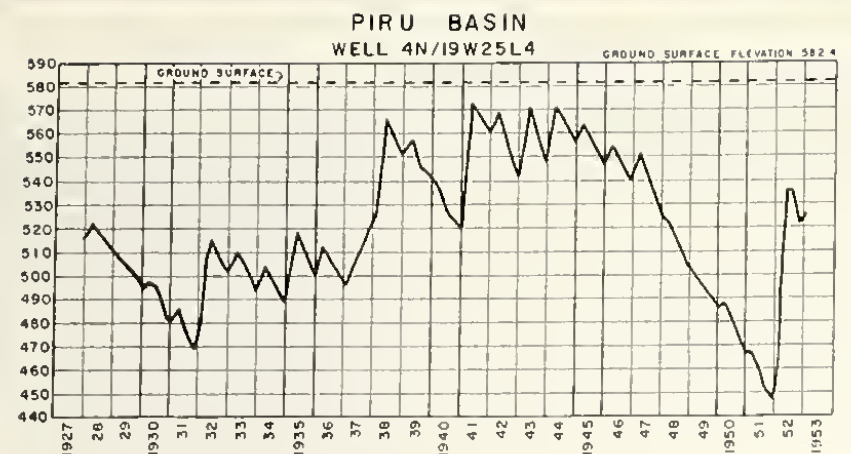
**LINES OF EQUAL CHANGE  
IN  
GROUND WATER ELEVATION**

SPRING OF 1944 TO FALL OF 1951





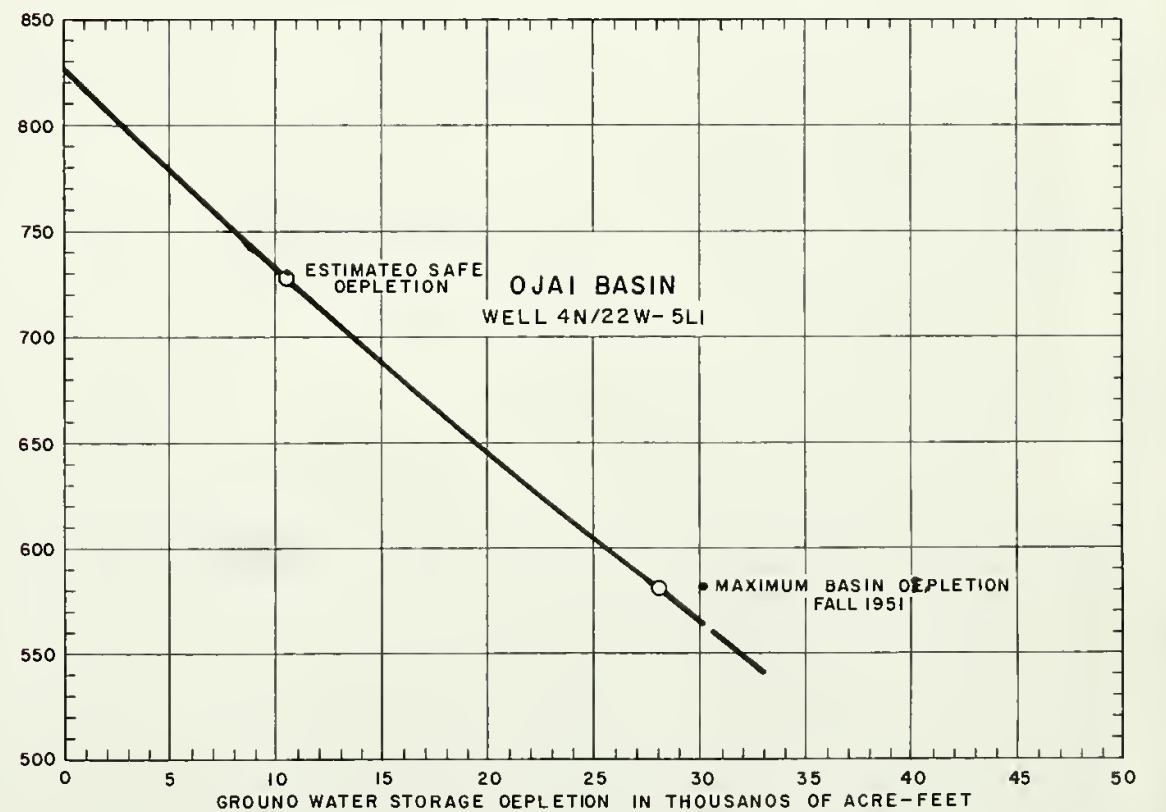
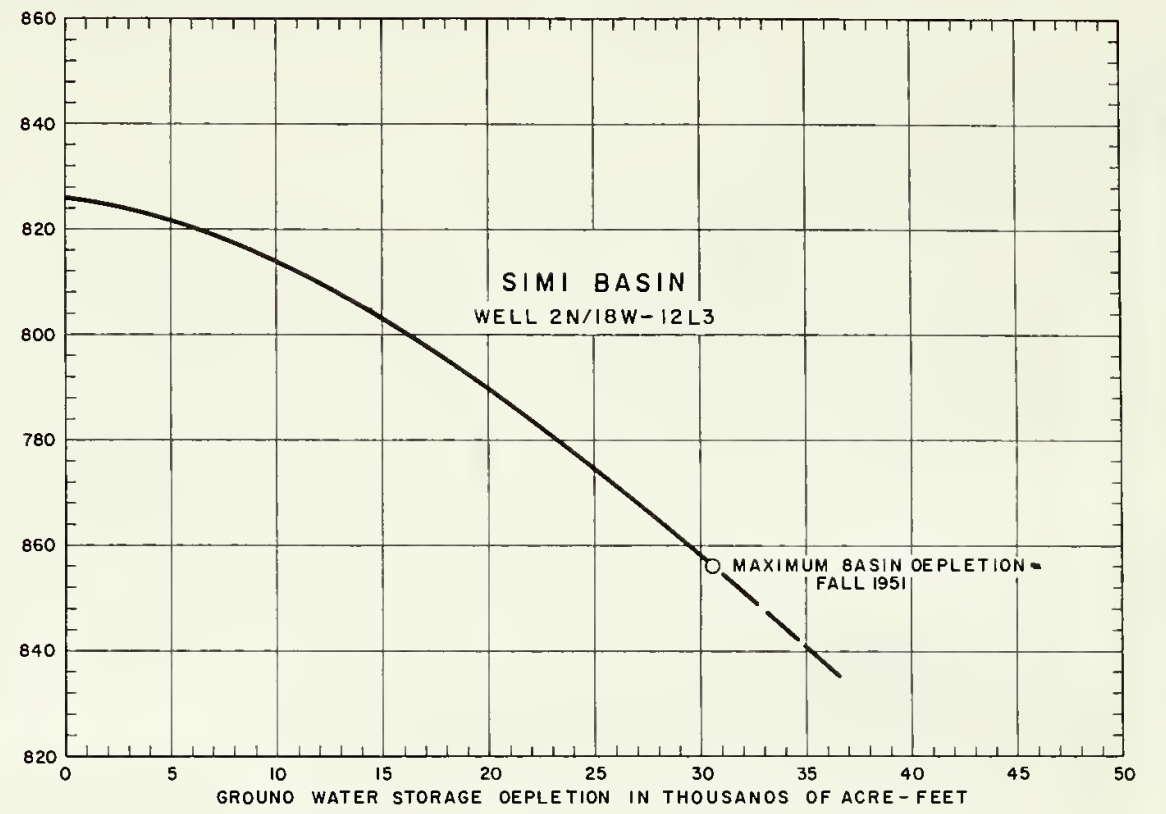
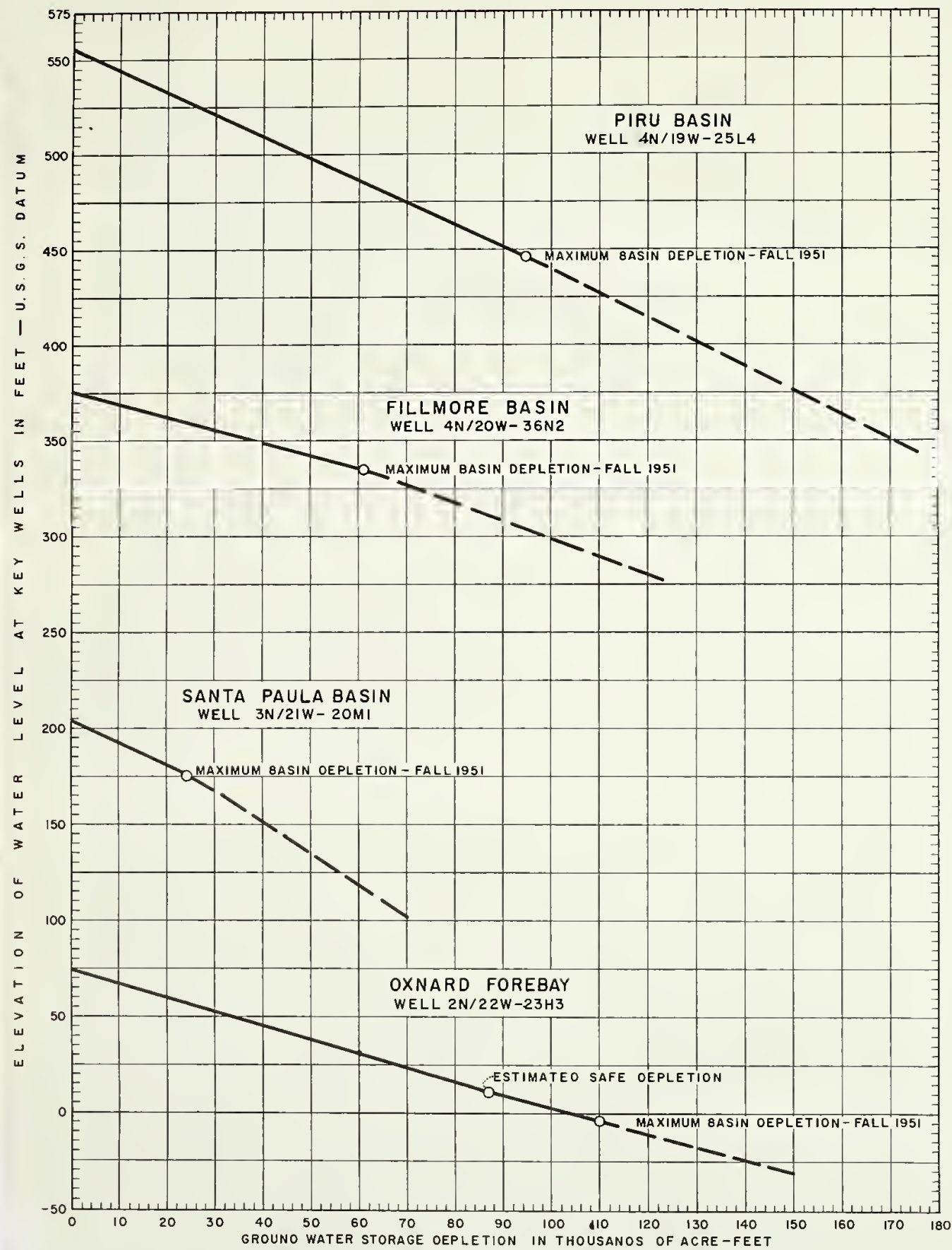
ELEVATION OF WATER LEVEL AT KEY WELLS IN FEET — U.S.G.S. DATUM



FLUCTUATION OF WATER LEVELS AT KEY WELLS

"F" INDICATES PERIOD DURING WHICH WELL FLOWED





RELATIONSHIP BETWEEN WATER LEVELS AT KEY WELLS  
AND GROUND WATER STORAGE DEPLETION

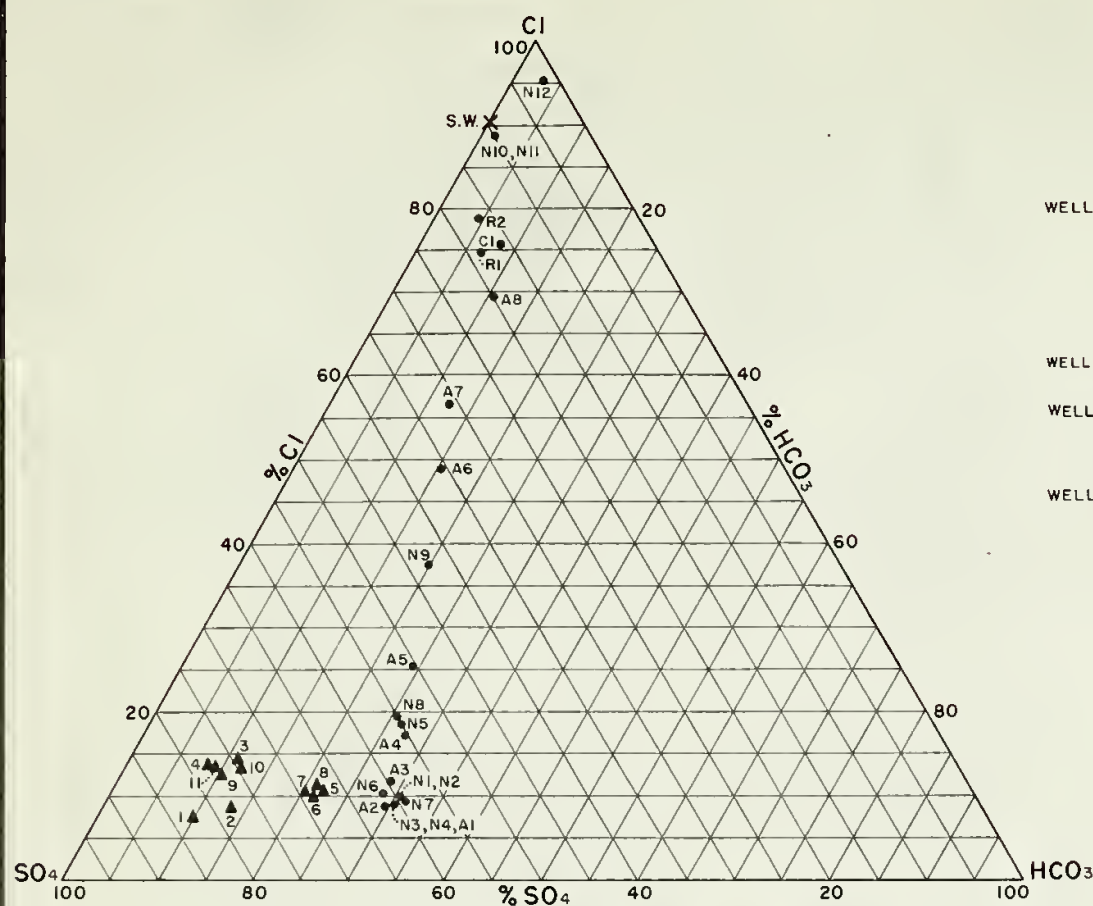


CHART A-CLASSIFICATION OF ANION CONSTITUENTS

POINT  
NUMBER

DATE  
SAMPLED

## CHART A

WELL IN/22W-29A2	A1	3-31-47
	A2	5-5-49
	A3	5-25-51
	A4	7-25-51
	A5	9-4-51
	A6	11-27-51
	A7	3-28-52
	A8	6-6-52
WELL IN/22W-29C1	C1	9-2-52
WELL IN/22W-20R1	R1	9-2-52
	R2	12-2-52
WELL IN/22W-20N1	N1	4-3-31
	N2	9-4-31
	N3	6-3-32
	N4	3-3-33
	N5	7-21-36
	N6	12-20-39
	N7	9-27-45
	N8	4-30-48
	N9	7-16-48
	N10	10-7-49
	N11	10-8-49
	N12	3-23-50

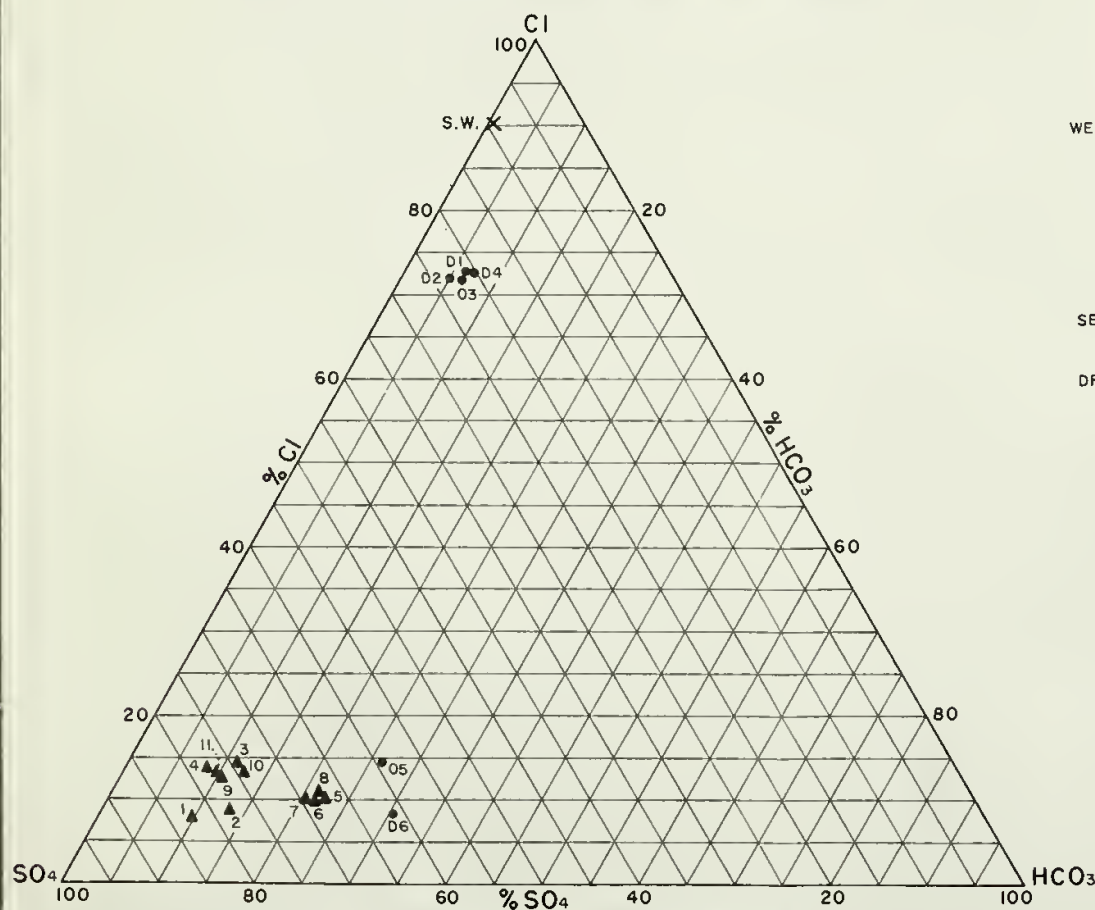


CHART B-CLASSIFICATION OF ANION CONSTITUENTS

POINT  
NUMBER

DATE  
SAMPLED

## CHART B

WELL IN/22W-28D1	O1	6-5-31
	D2	6-9-31
	O3	6-26-31 (Low Tide)
	D4	6-26-31 (High Tide)
	D5	6-3-32
	O6	3-3-33

## CHARTS A AND B

SEA WATER	S.W.	5-1-52
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DRAINAGE DITCHES		LOCATION
1	6-4-52	IN/22W-7J
2	1-14-53	IN/22W-7J
3	1-14-53	IN/22W-18A
4	8-4-52	IN/22W-18B
5	8-4-52	IN/22W-21B
6	6-6-52	IN/22W-21F
7	1-14-53	IN/22W-21F
8	8-4-52	IN/22W-21O
9	6-6-52	IN/22W-27C
10	8-4-52	IN/22W-27C
11	1-14-53	IN/22W-27C

## LEGEND

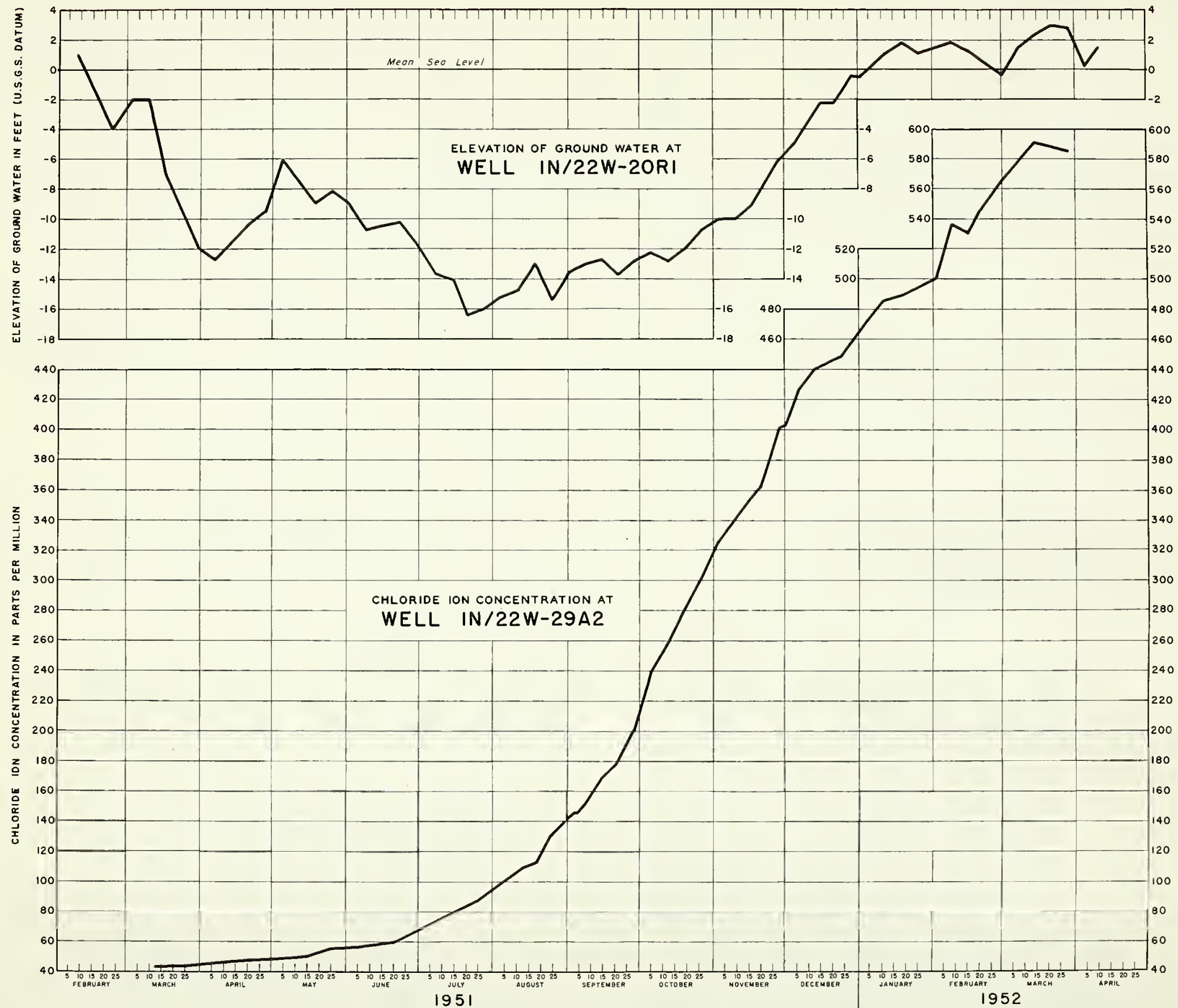
- WELLS
- ▲ GROUND WATER ORAINAGE
- ✱ SEA WATER

NOTE— SEE PLATE 11 FOR WELL LOCATIONS.  
SEE PLATE 7 FOR GROUND WATER  
DRAINAGE SAMPLING POINTS

## MINERAL CHARACTER OF GROUND WATERS IN VICINITY OF PORT HUENEME AND POINT MUGU

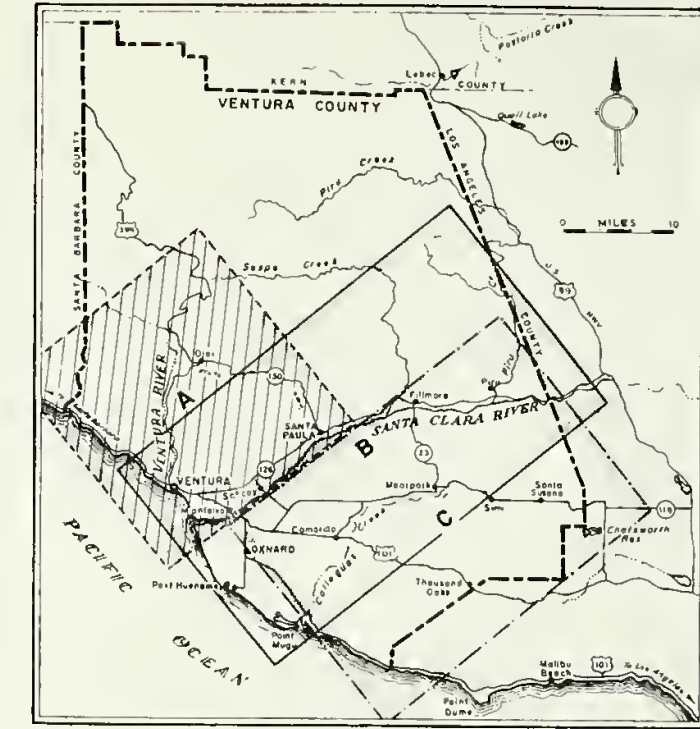
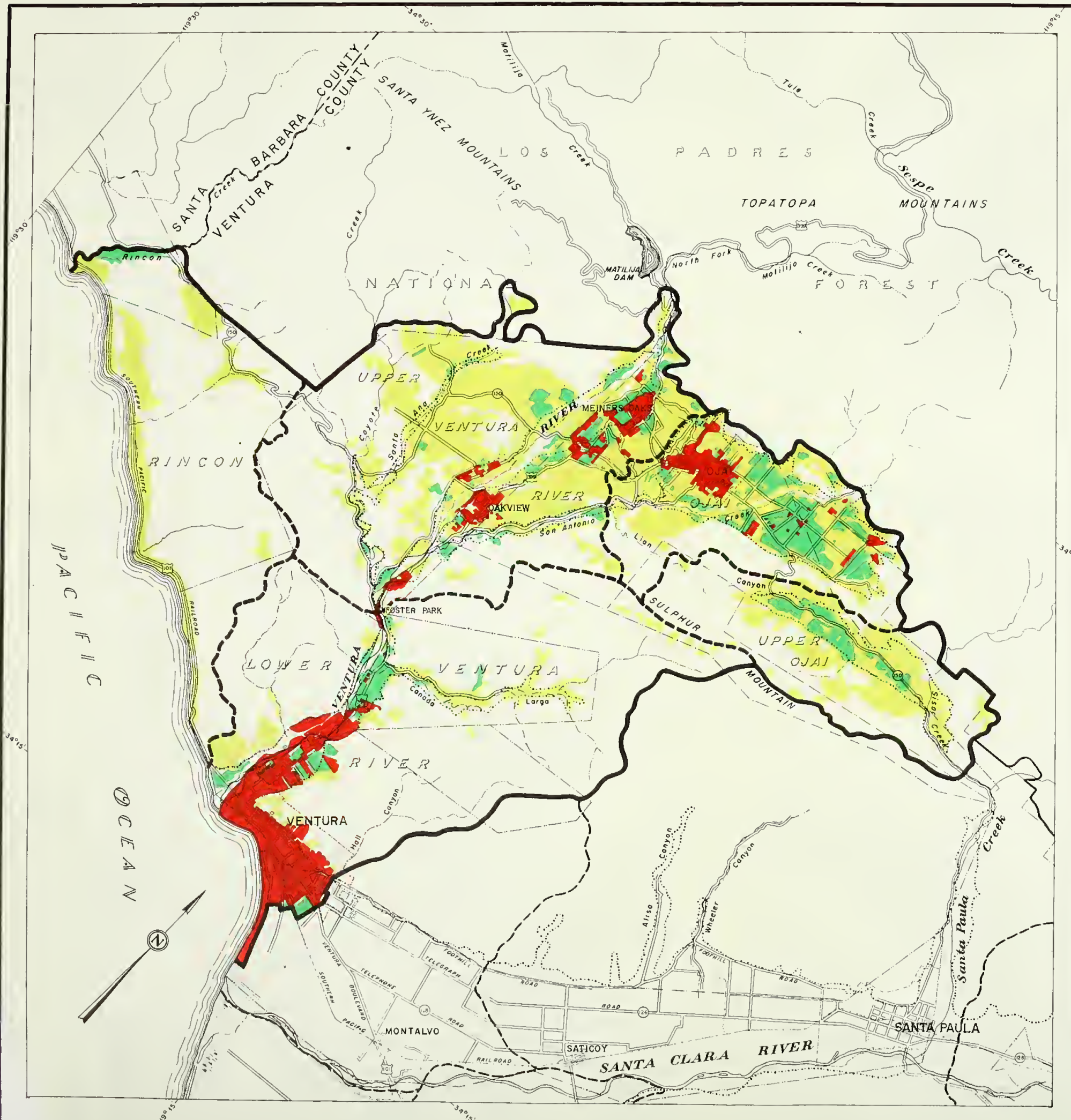






ELEVATION OF GROUND WATER AND CHLORIDE ION CONCENTRATION





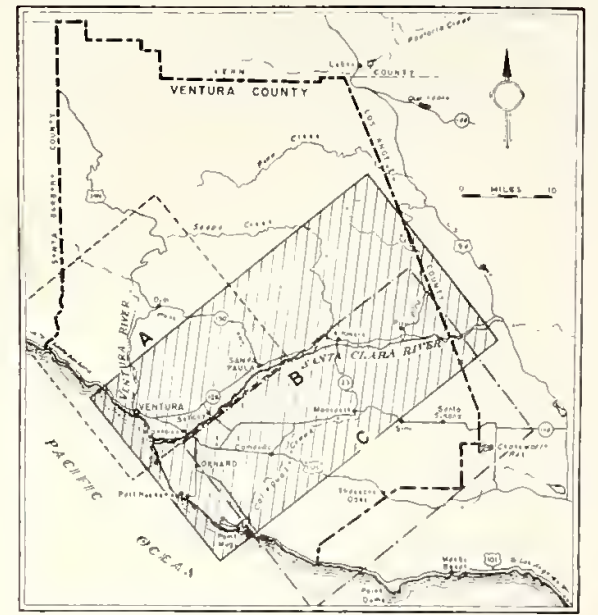
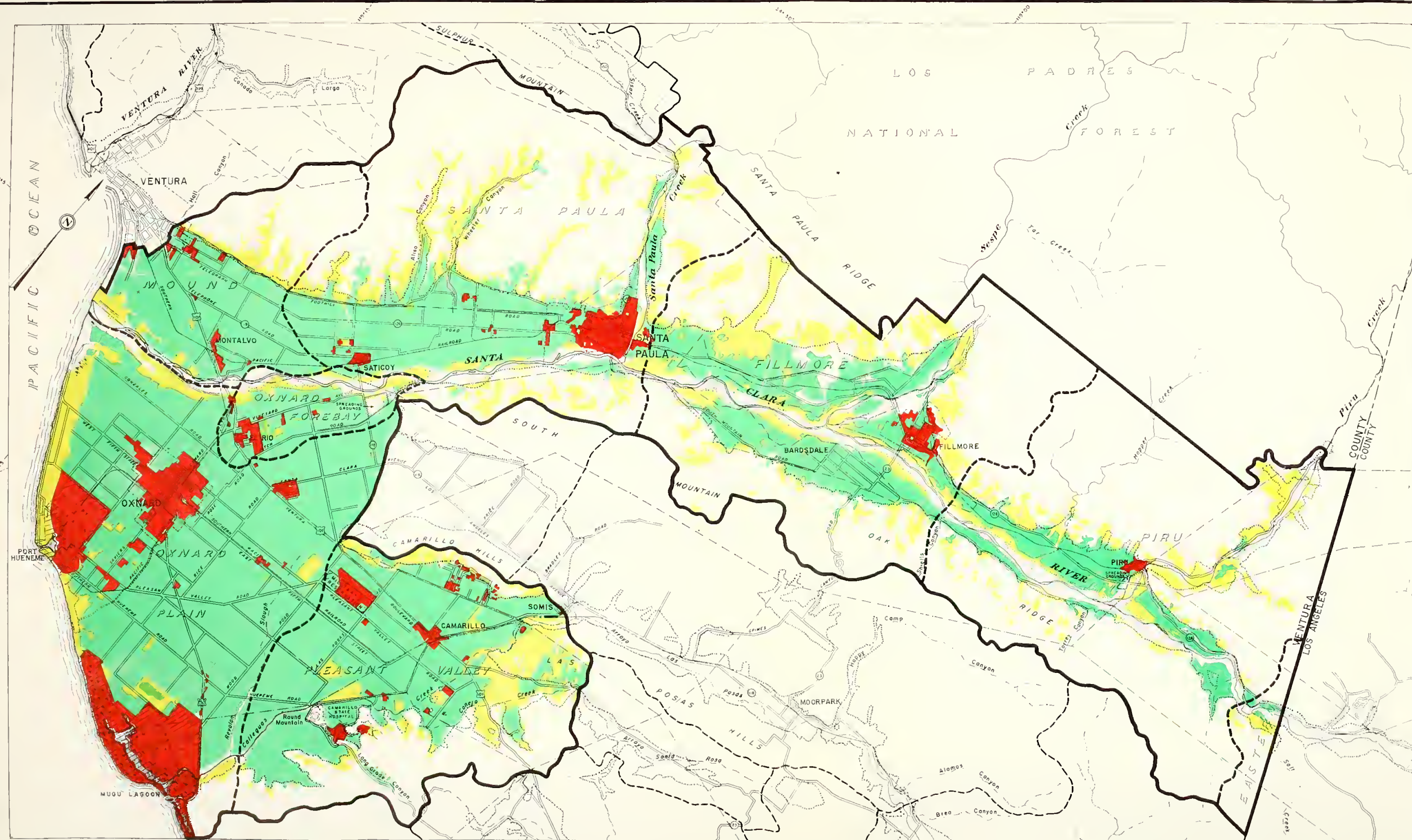
KEY MAP

- LEGEND**
- HYDROLOGIC UNIT BOUNDARY
  - - - SUBUNIT BOUNDARY
  - ..... APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - OJAI NAME OF SUBUNIT
  - IRRIGATED LANDS
  - IRRIGABLE AND HABITABLE LANDS
  - URBAN AREAS

STATE OF CALIFORNIA  
 DEPARTMENT OF PUBLIC WORKS  
 DIVISION OF WATER RESOURCES  
 VENTURA COUNTY INVESTIGATION  
 VENTURA HYDROLOGIC UNIT  
 PRESENT AND PROBABLE ULTIMATE LAND USE  
 1950

Scale of miles  
 0 1 2 3





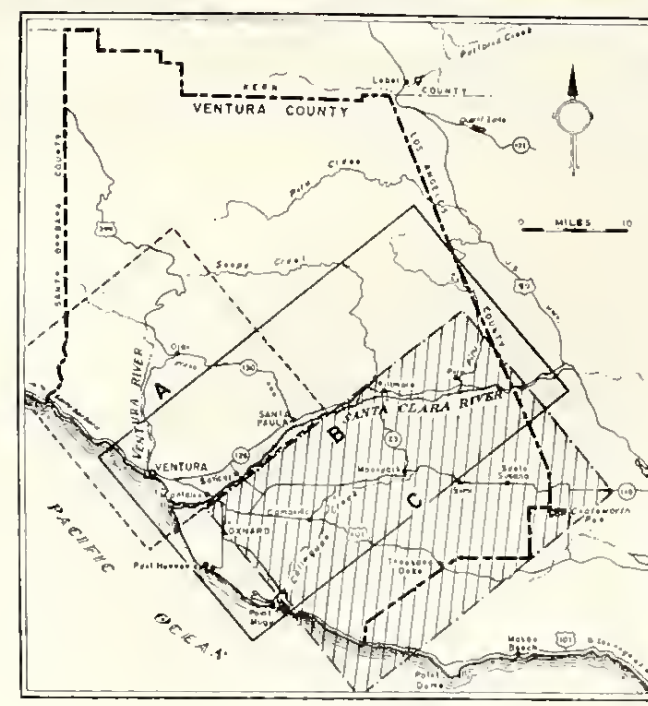
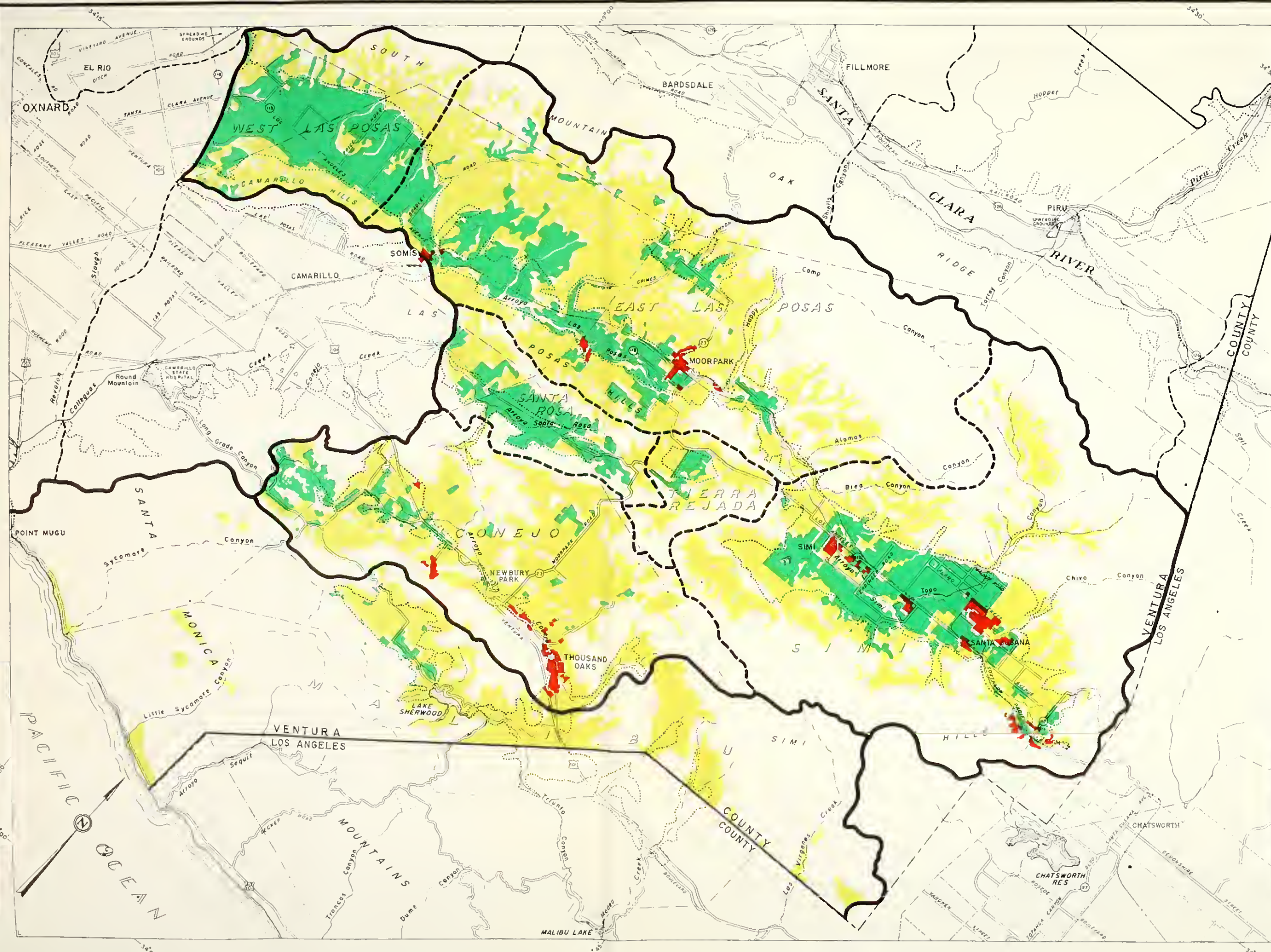
KEY MAP

- LEGEND
- HYDROLOGIC UNIT BOUNDARY
  - - - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - PIRU NAME OF SUBUNIT
  - IRRIGATED LANDS
  - IRRIGABLE AND HABITABLE LANDS
  - URBAN AREAS

STATE OF CALIFORNIA  
 DEPARTMENT OF PUBLIC WORKS  
 DIVISION OF WATER RESOURCES  
 VENTURA COUNTY INVESTIGATION  
 SANTA CLARA RIVER HYDROLOGIC UNIT  
 PRESENT AND PROBABLE ULTIMATE LAND USE  
 1950










KEY MAP

- LEGEND**
- HYDROLOGIC UNIT BOUNDARY
  - SUBUNIT BOUNDARY
  - APPROXIMATE BOUNDARY OF VALLEY FLOOR
  - SIMI NAME OF SUBUNIT
  - IRRIGATED LANDS
  - IRRIGABLE AND HABITABLE LANDS
  - URBAN AREAS

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
CALLEGUAS-CONEJO AND MALIBU HYDROLOGIC UNITS  
PRESENT AND PROBABLE ULTIMATE LAND USE  
1950



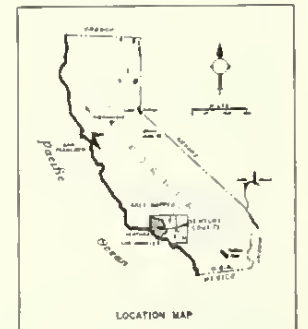


 PRINCIPAL DRAINAGE AREA BOUNDARY  
 SECONDARY DRAINAGE AREA BOUNDARY  
 POTENTIAL LOCAL WATER STORAGE DEVELOPMENTS AND CONVEYANCE UNITS FOR IMPORTATION OF WATER TO VENTURA COUNTY  


STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

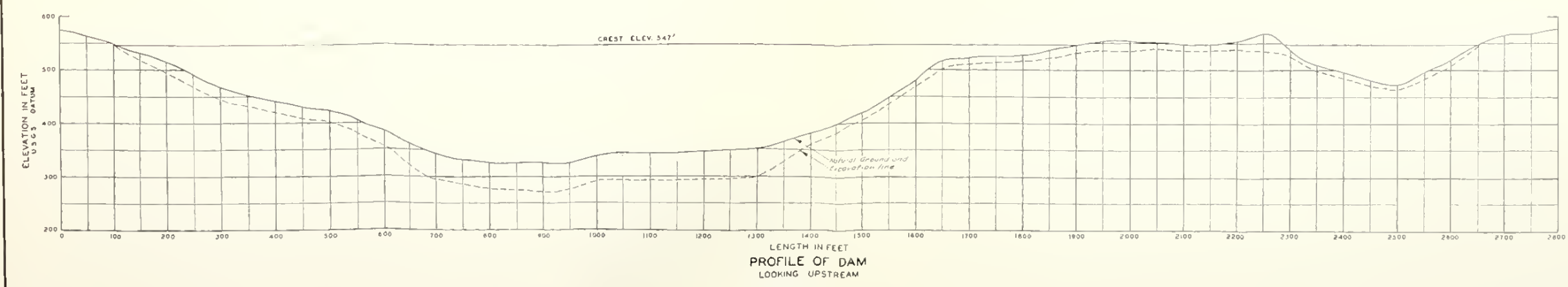
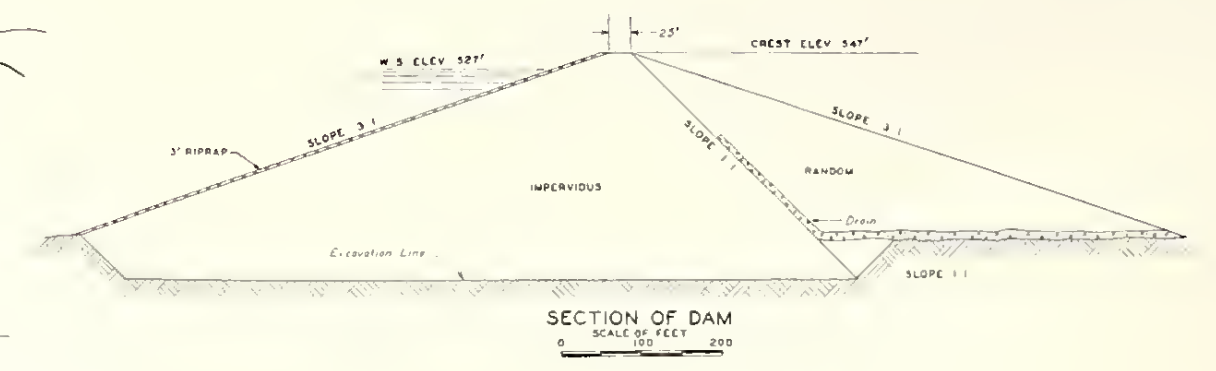
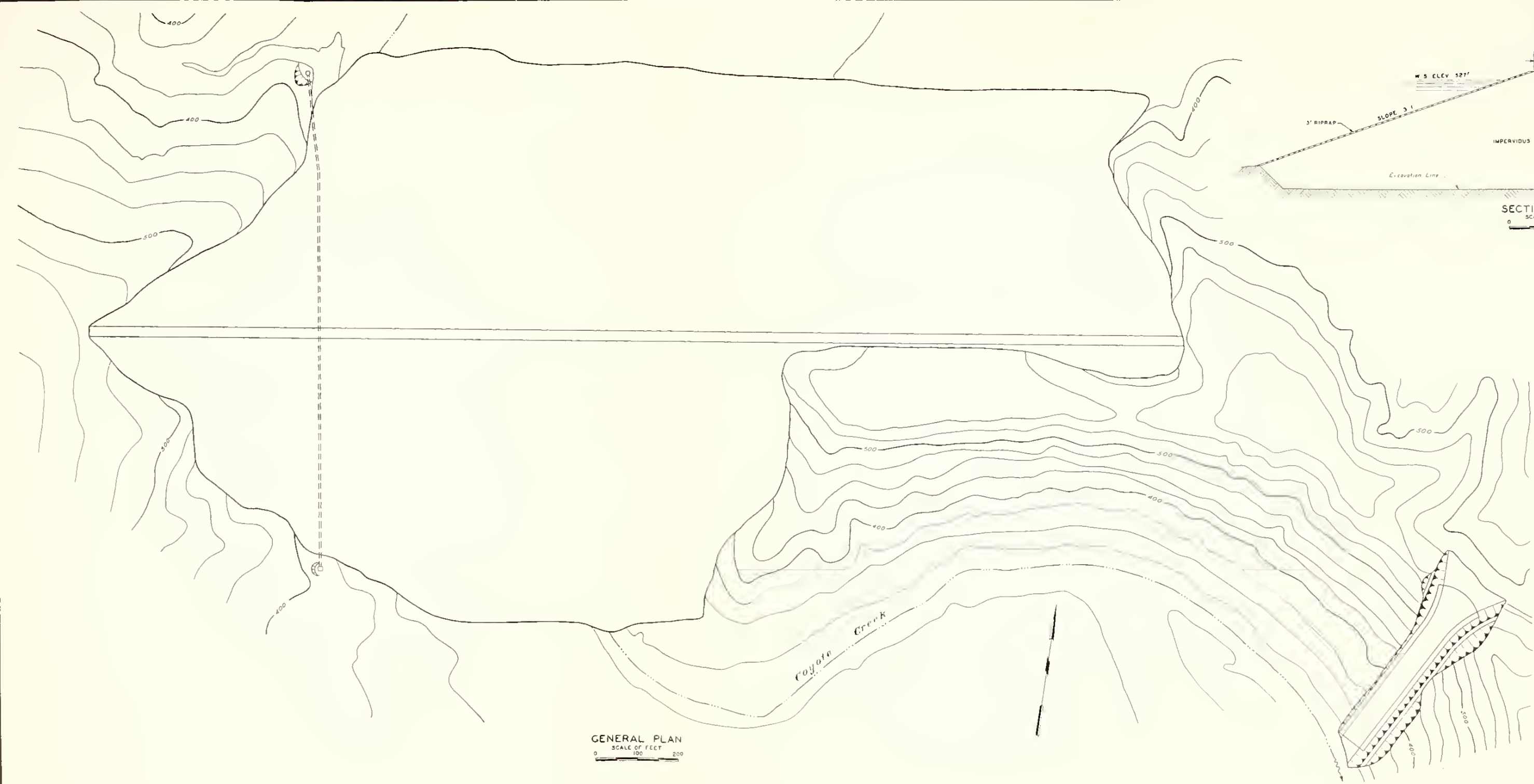
POTENTIAL  
LOCAL WATER STORAGE DEVELOPMENTS  
AND  
CONVEYANCE UNITS FOR IMPORTATION OF WATER  
TO VENTURA COUNTY

1953

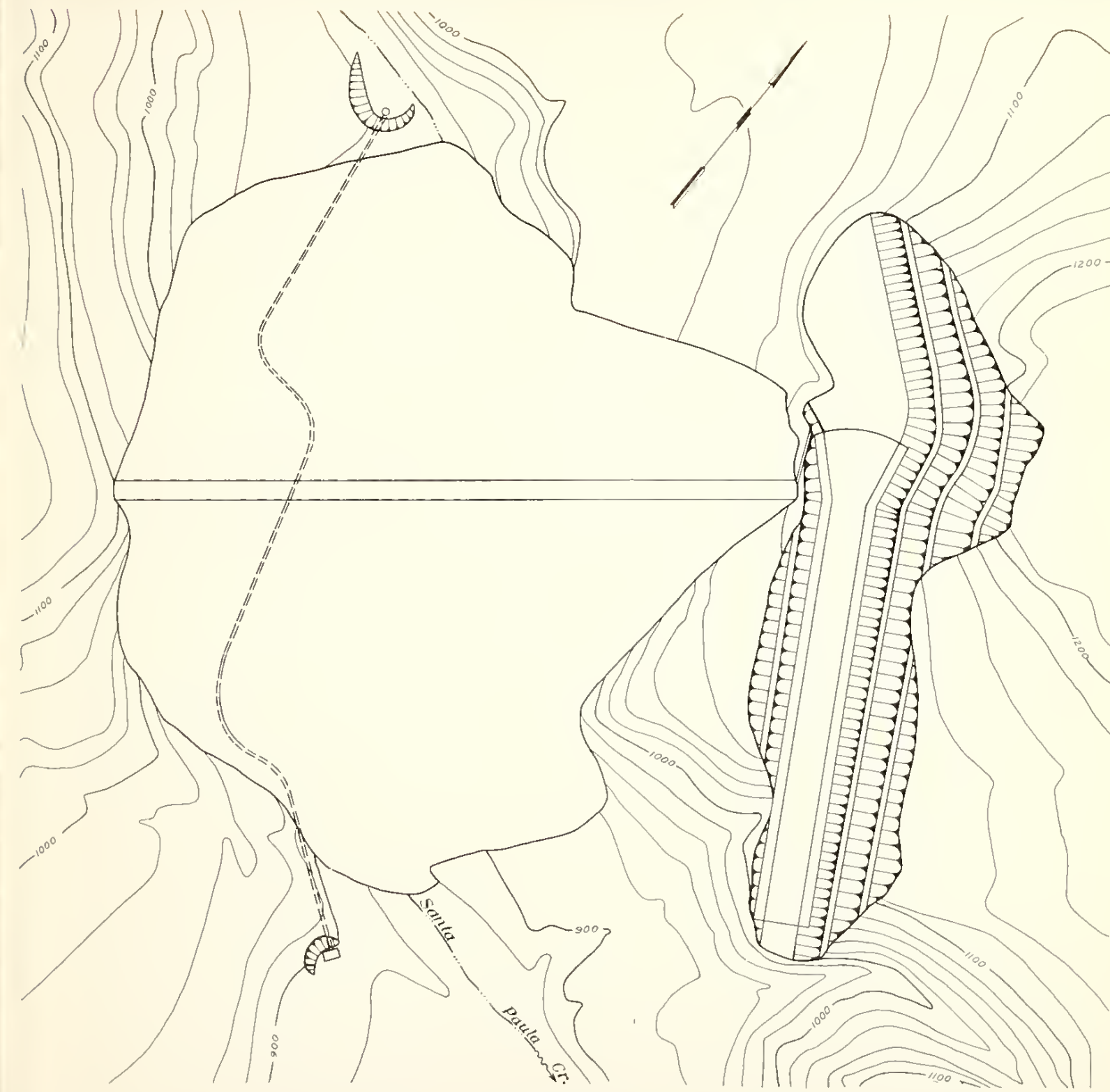




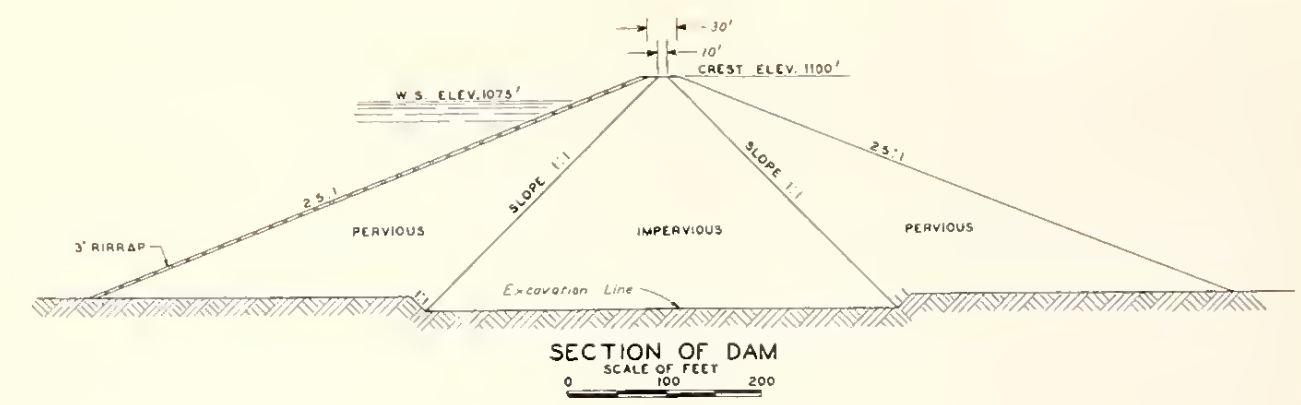




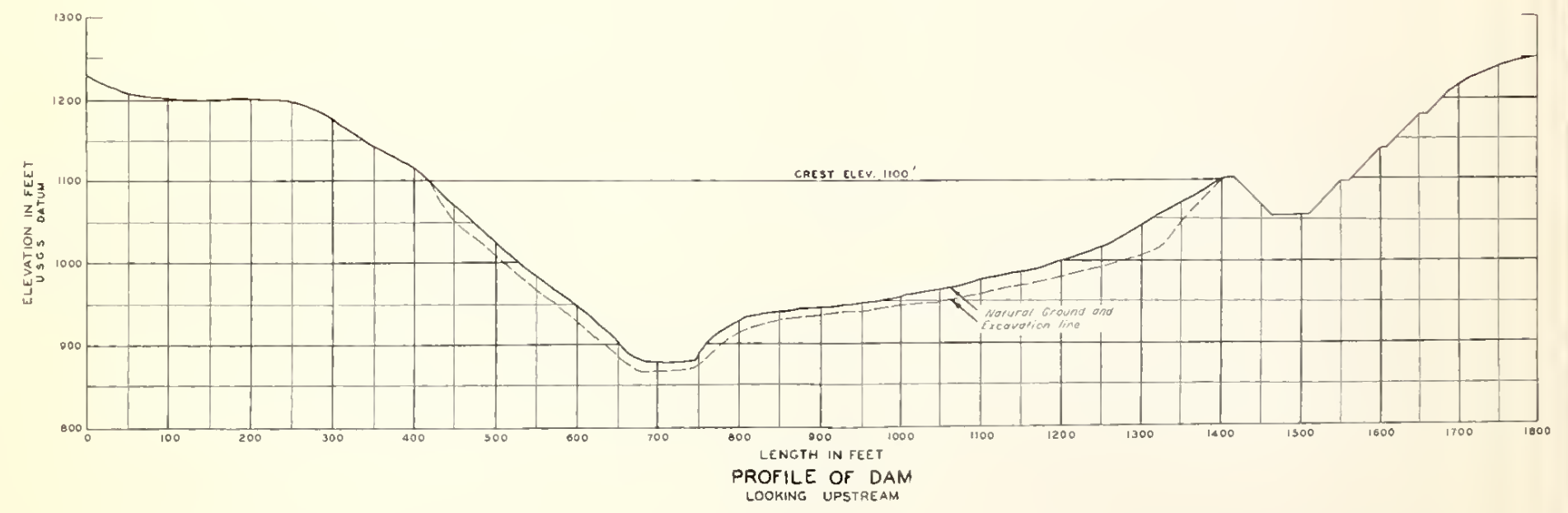
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**CASITAS DAM**  
ON  
**COYOTE CREEK**  
RESERVOIR STORAGE CAPACITY OF 130,000 ACRE-Feet



GENERAL PLAN  
SCALE OF FEET  
0 100 200

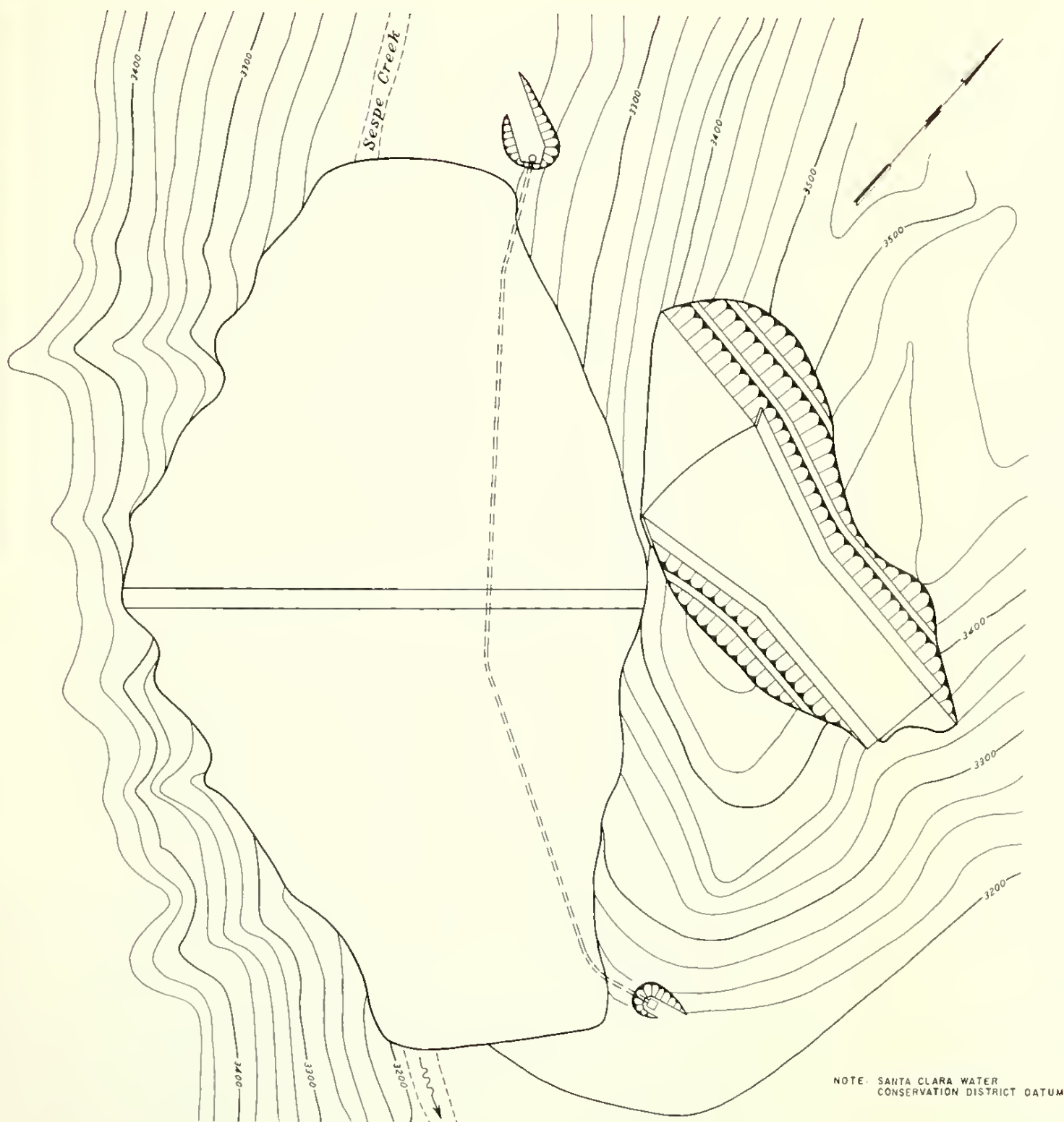


SECTION OF DAM  
SCALE OF FEET  
0 100 200

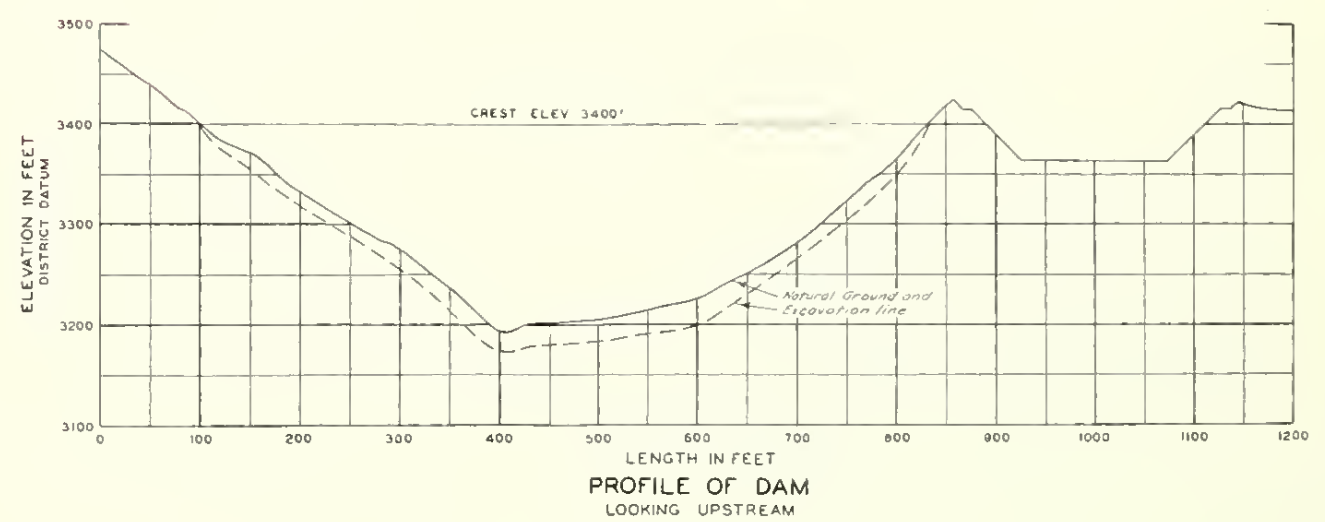
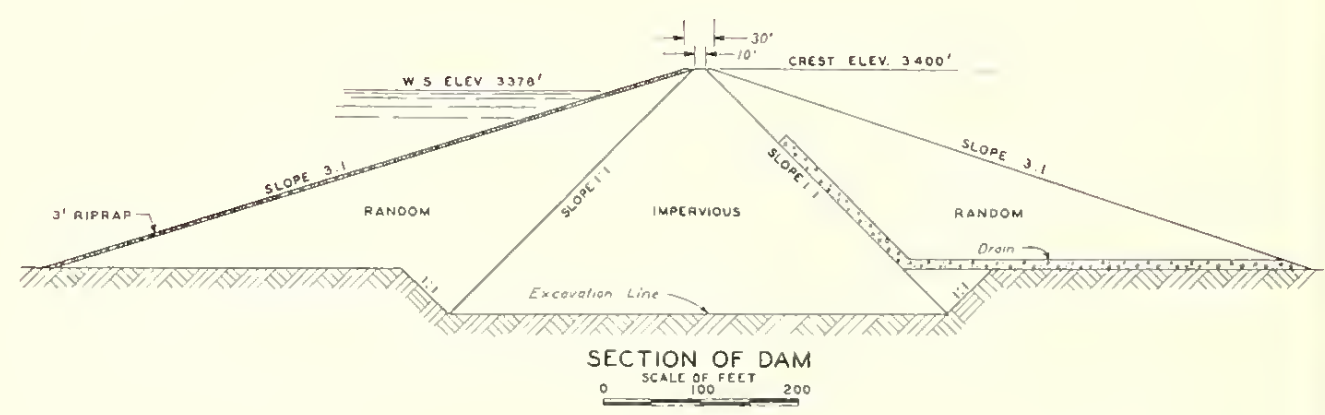


PROFILE OF DAM  
LOOKING UPSTREAM

STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**FERNDAL DAM**  
ON  
**SANTA PAULA CREEK**  
RESERVOIR STORAGE CAPACITY OF 12,000 ACRE-Feet

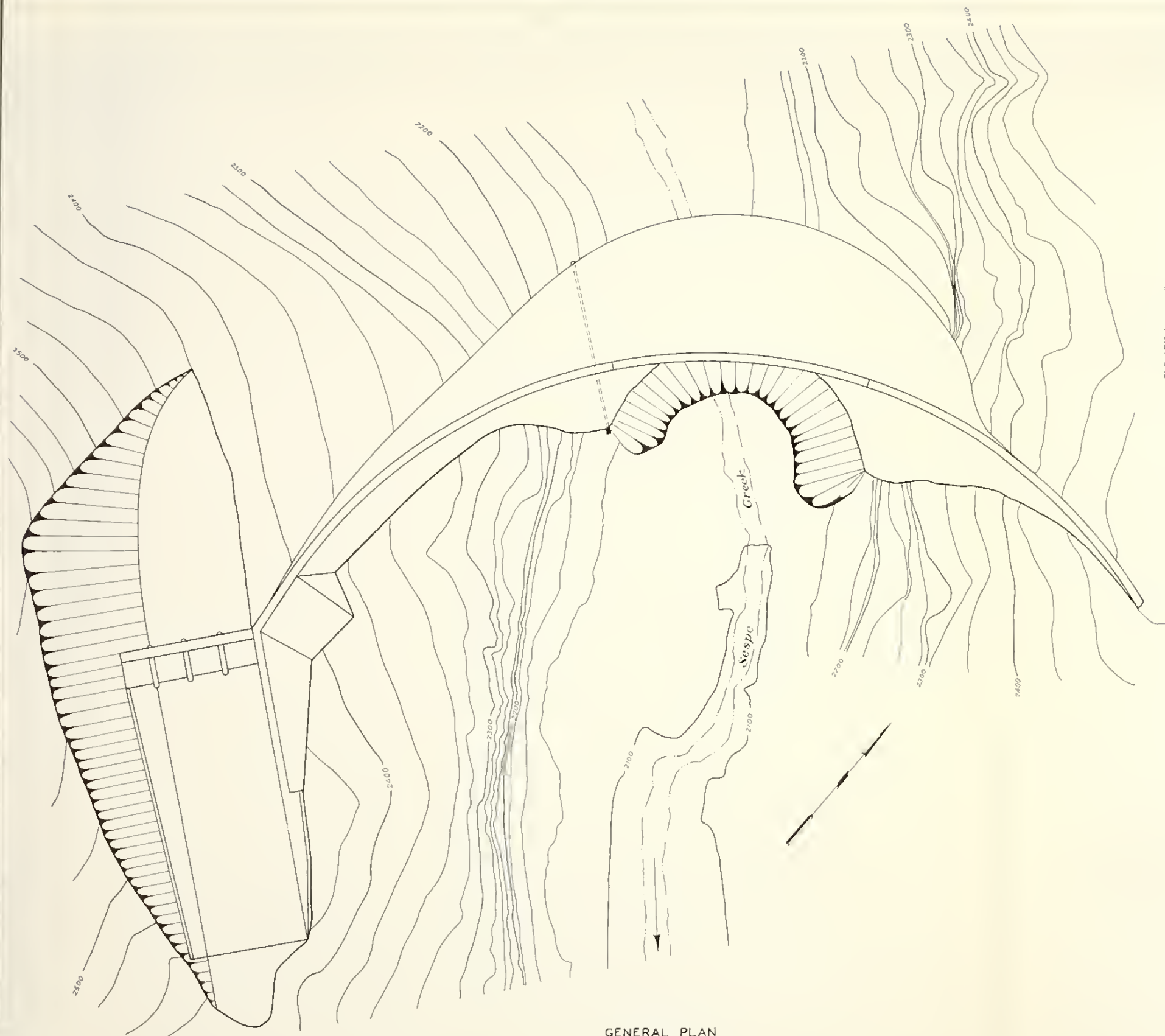


GENERAL PLAN  
SCALE OF FEET  
0 100 200

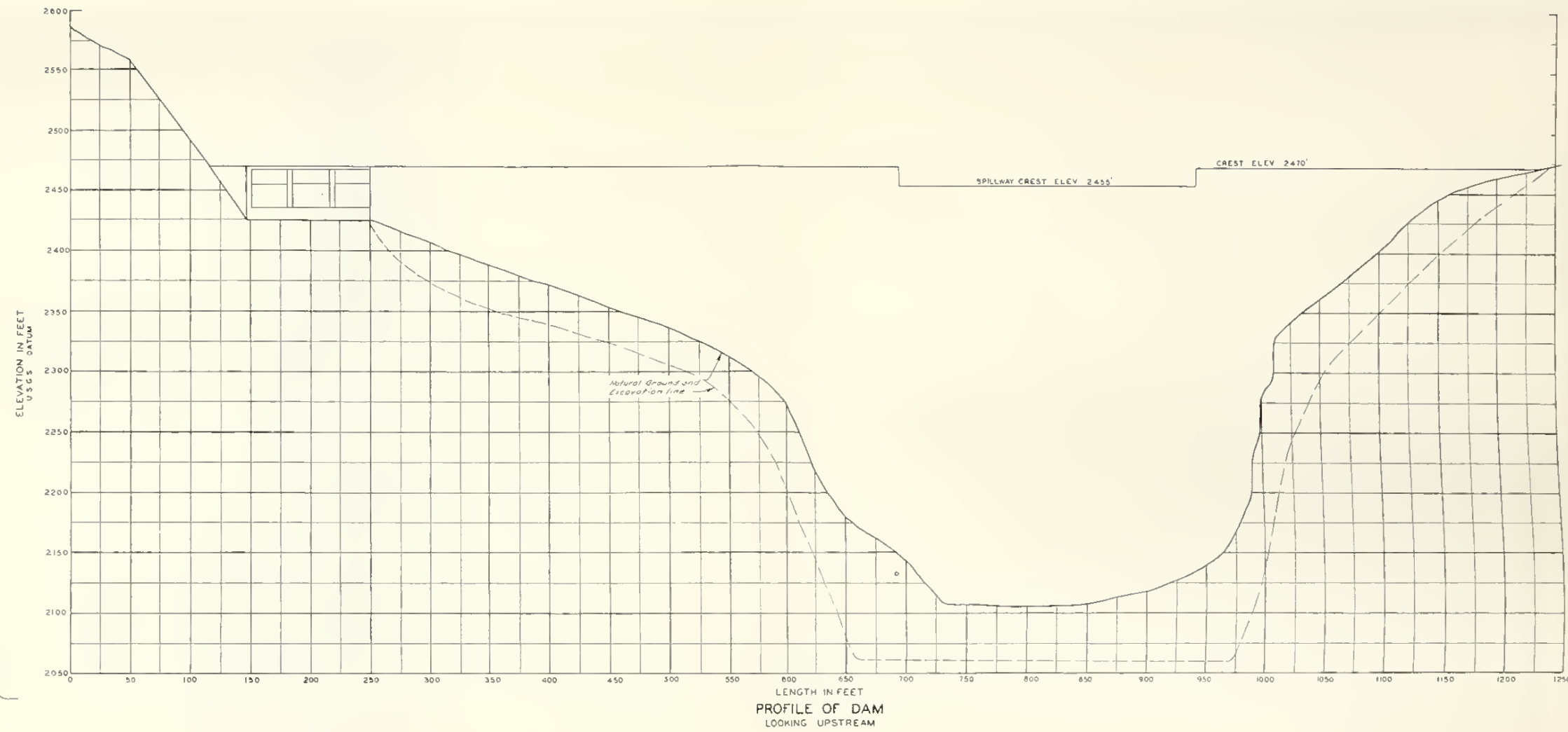


WATER RESOURCES  
DIVISION  
VENTURA COUNTY INVESTIGATION  
**COLD SPRING DAM**  
ON  
**SEspe CREEK**  
RESERVOIR STORAGE CAPACITY OF 35,000 ACRE-FeET

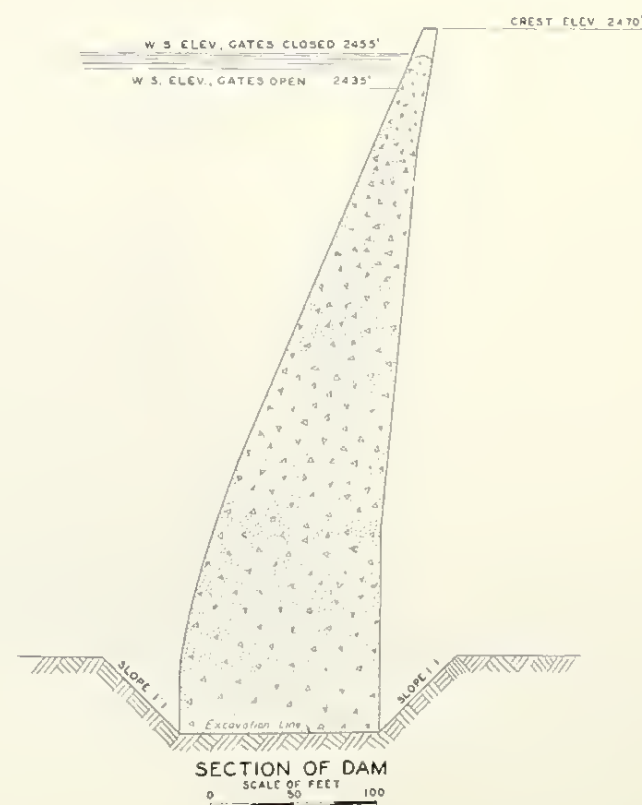




GENERAL PLAN  
SCALE OF FEET  
0 50 100

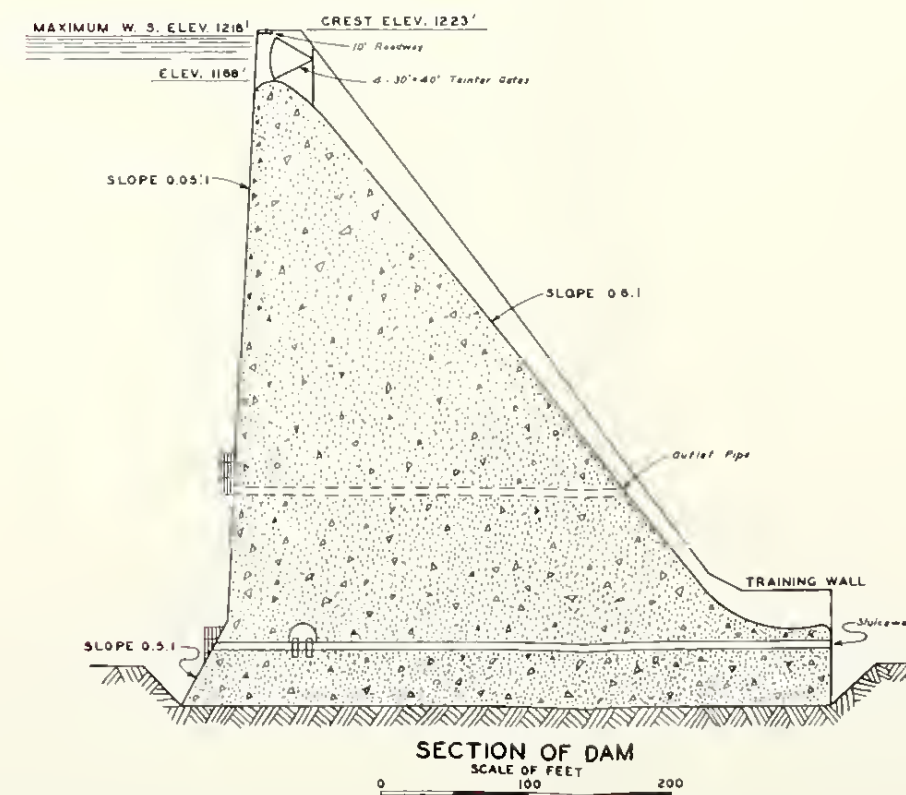
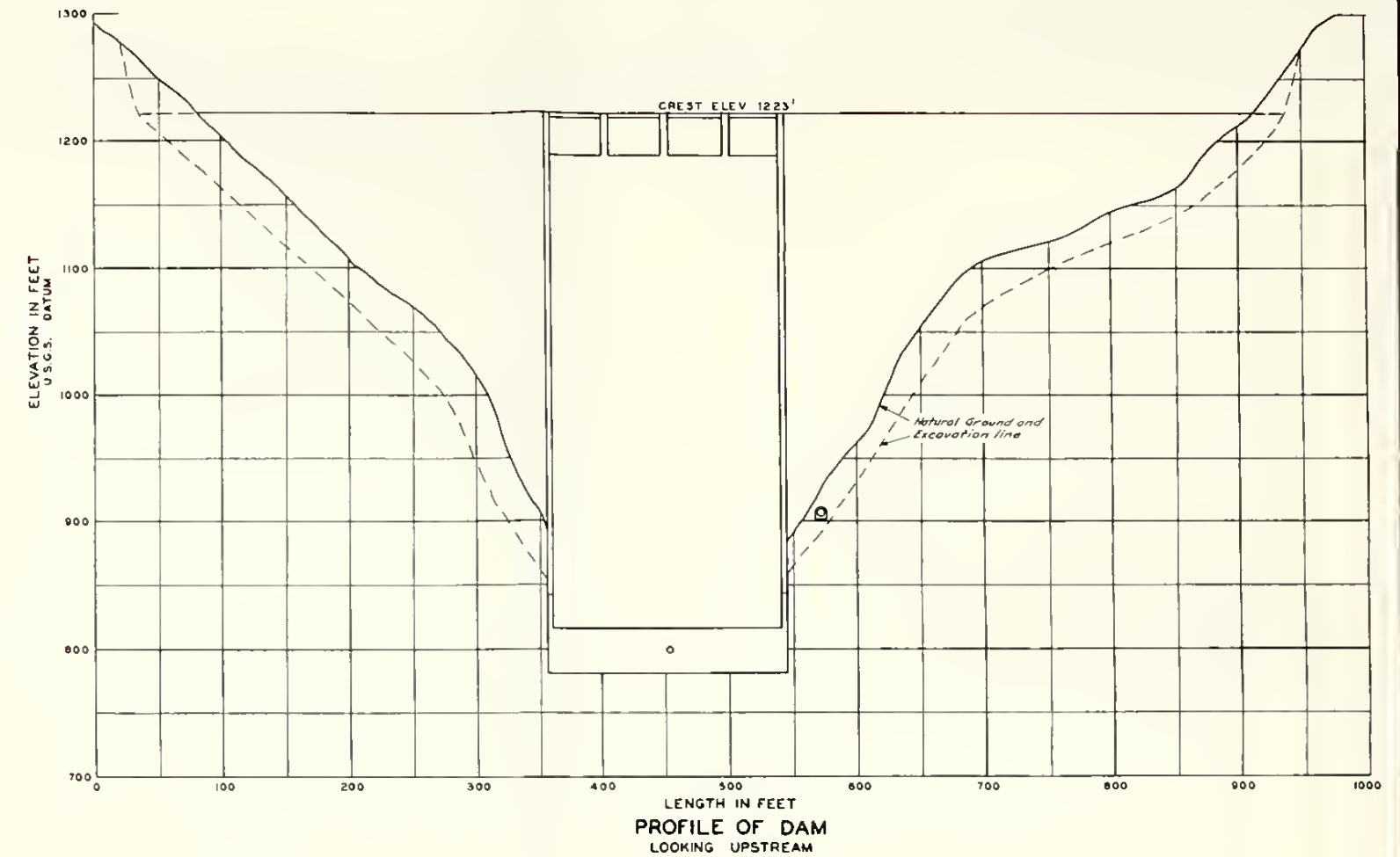
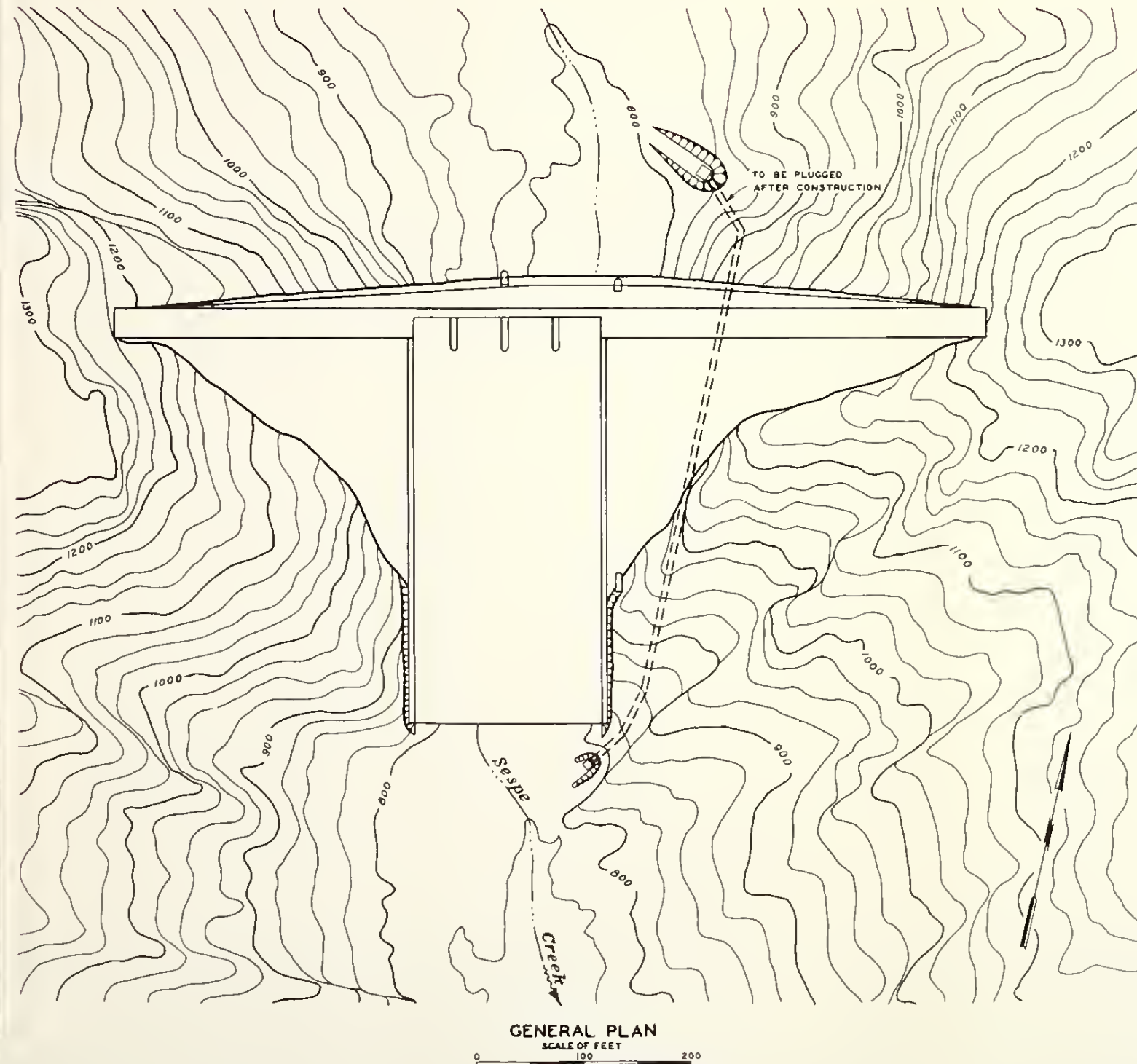


PROFILE OF DAM  
LOOKING UPSTREAM



SECTION OF DAM  
SCALE OF FEET  
0 50 100

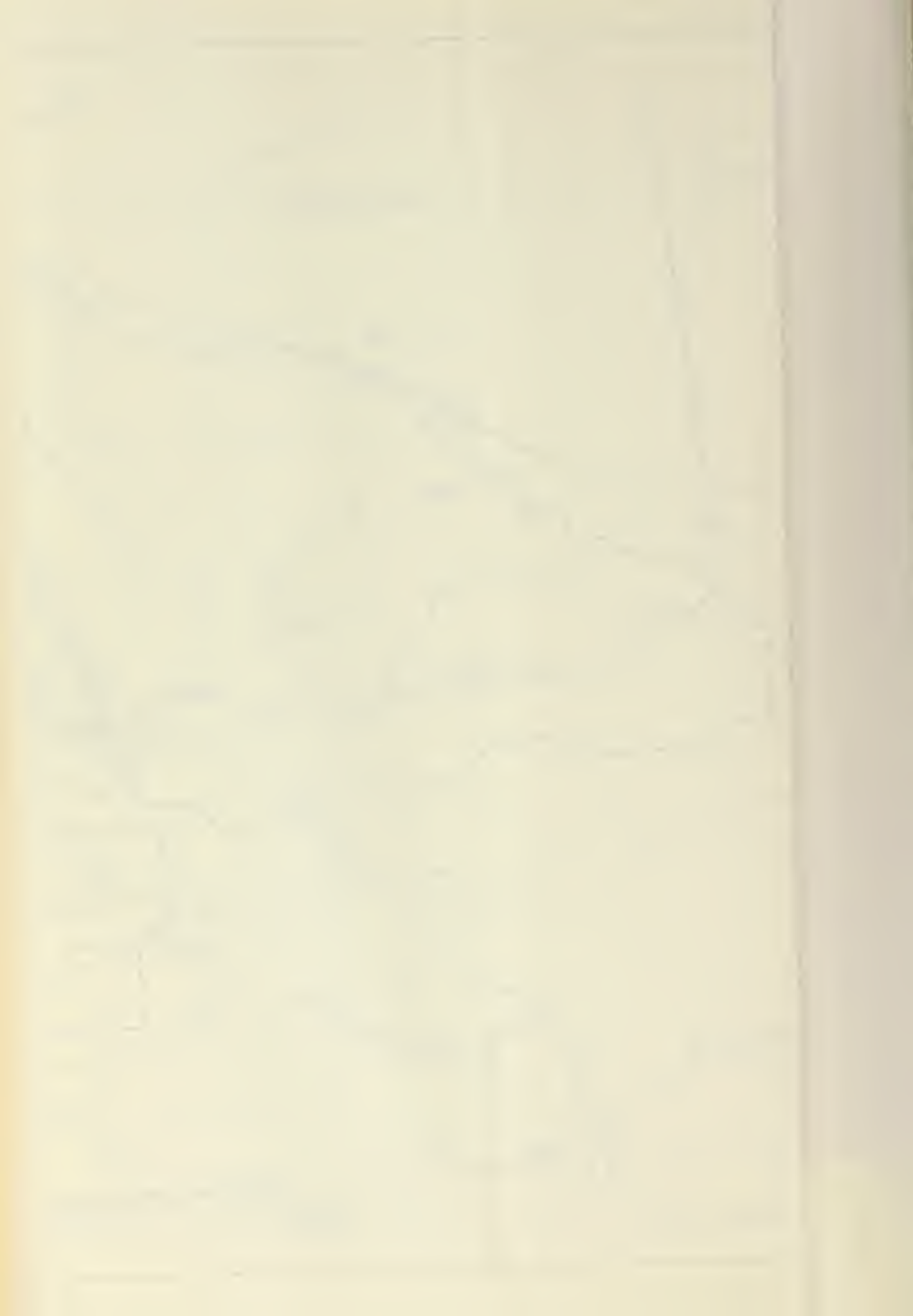
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**TOPATOPA DAM**  
ON  
**SESPÉ CREEK**  
RESERVOIR STORAGE CAPACITY OF 100,000 ACRE-Feet



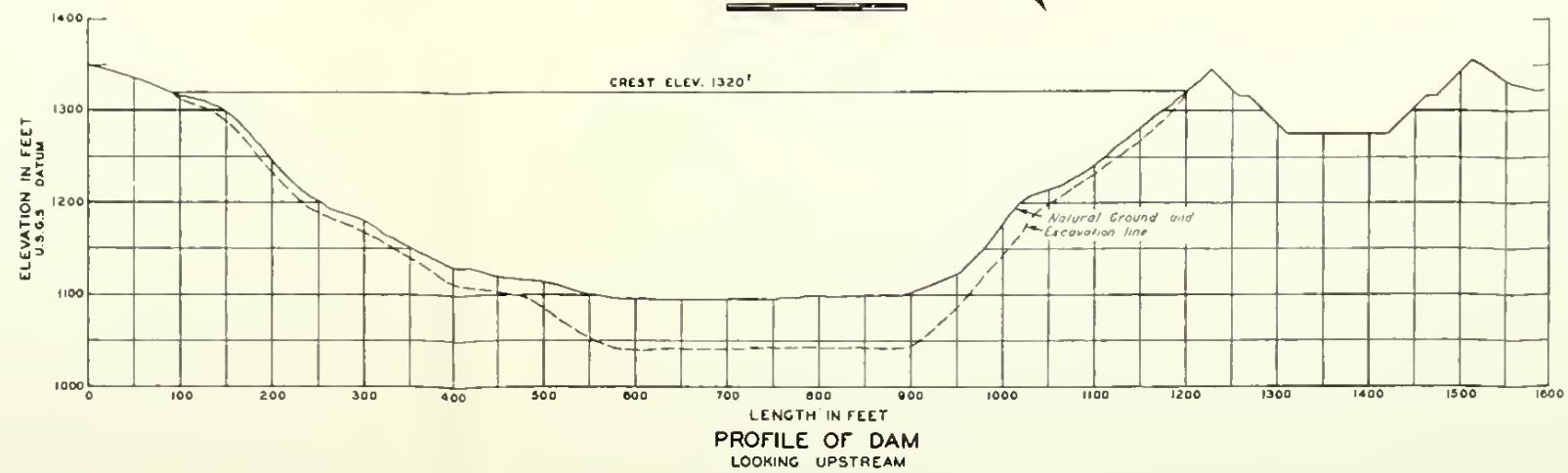
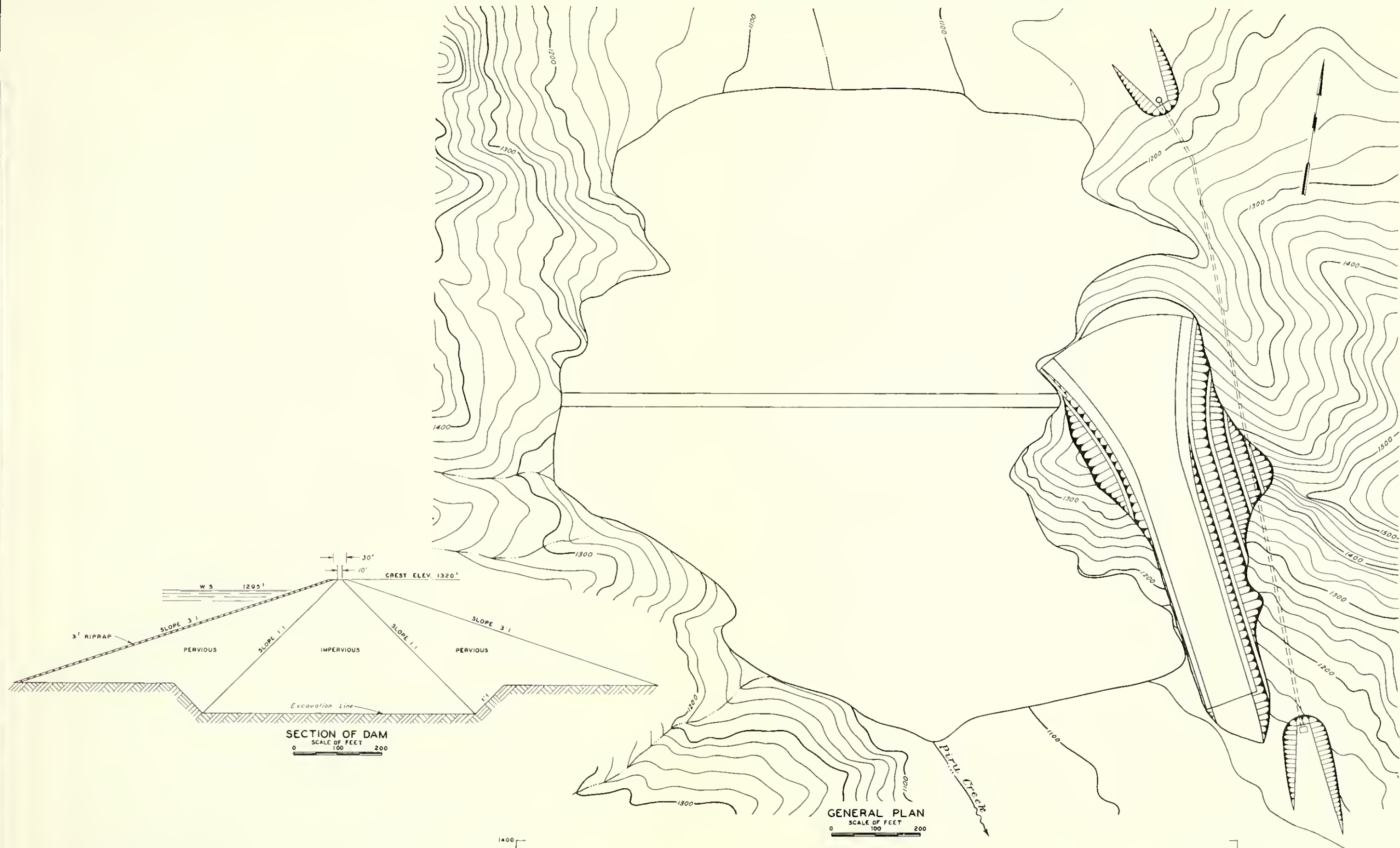
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

**HAMMEL DAM**  
ON  
**SESPÉ CREEK**

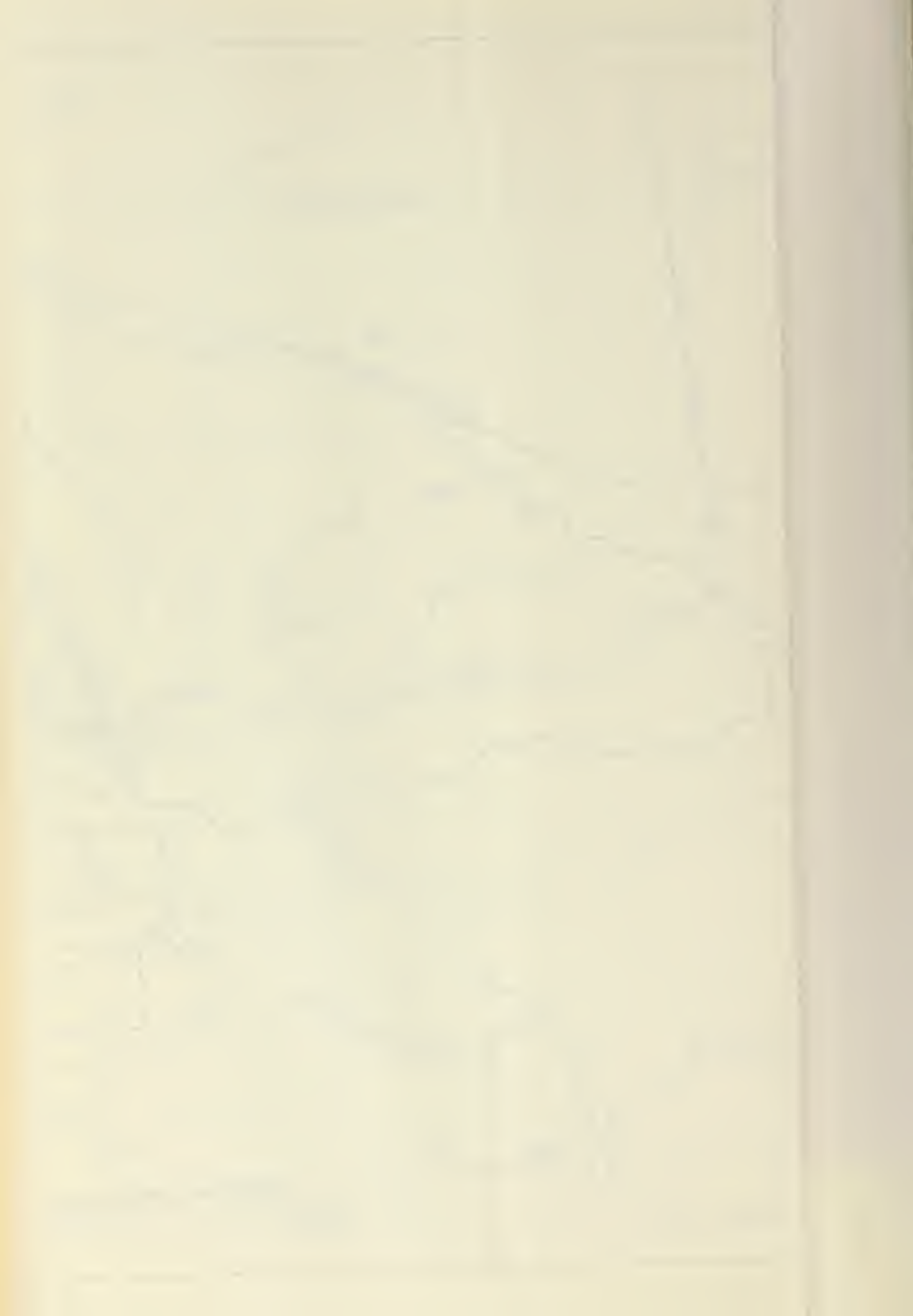
RESERVOIR STORAGE CAPACITY OF 50,000 ACRE-Feet

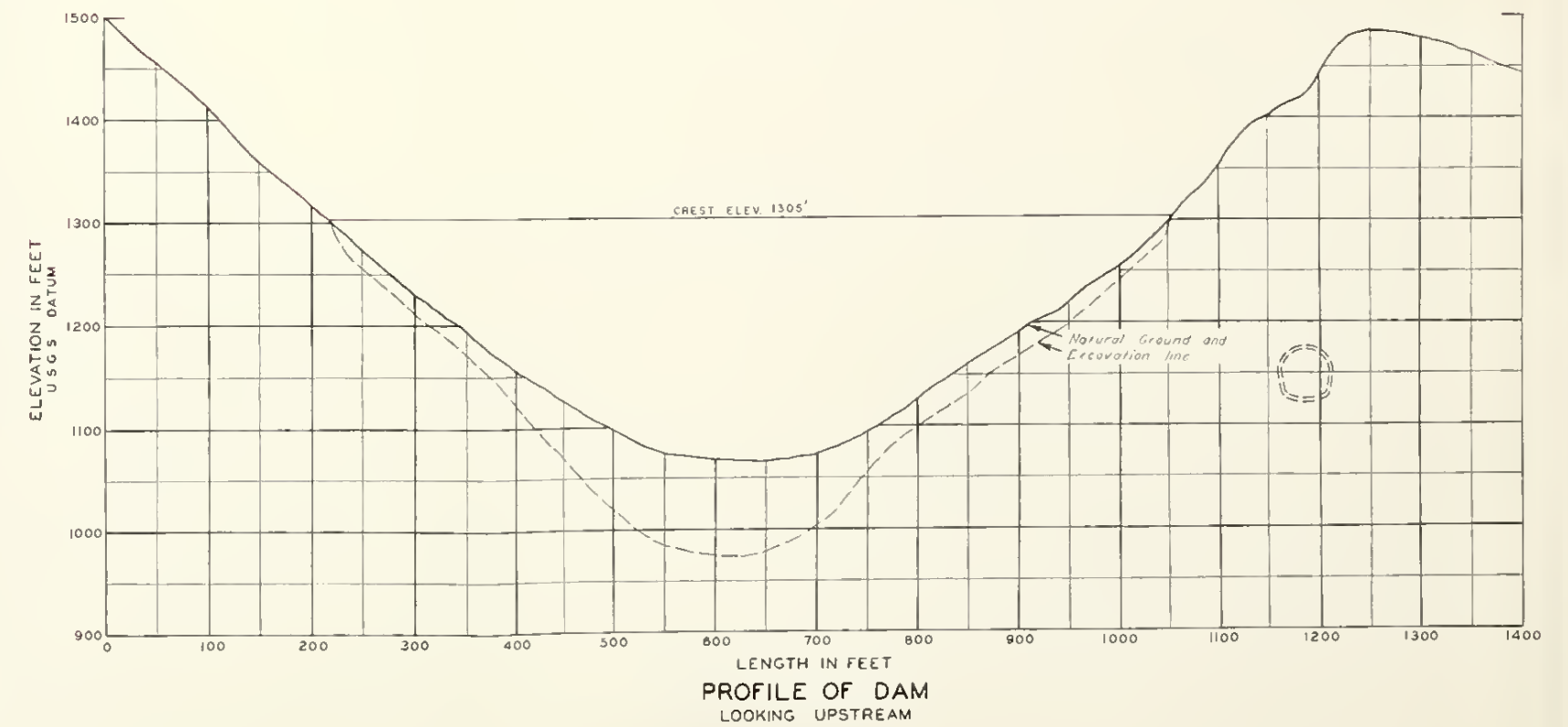
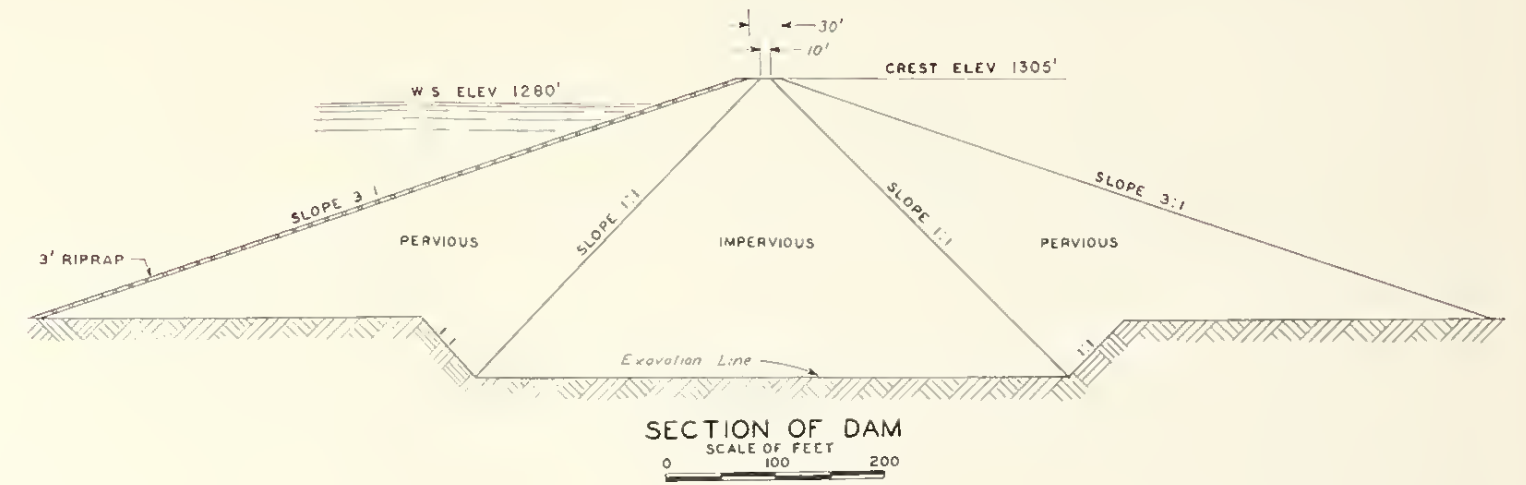
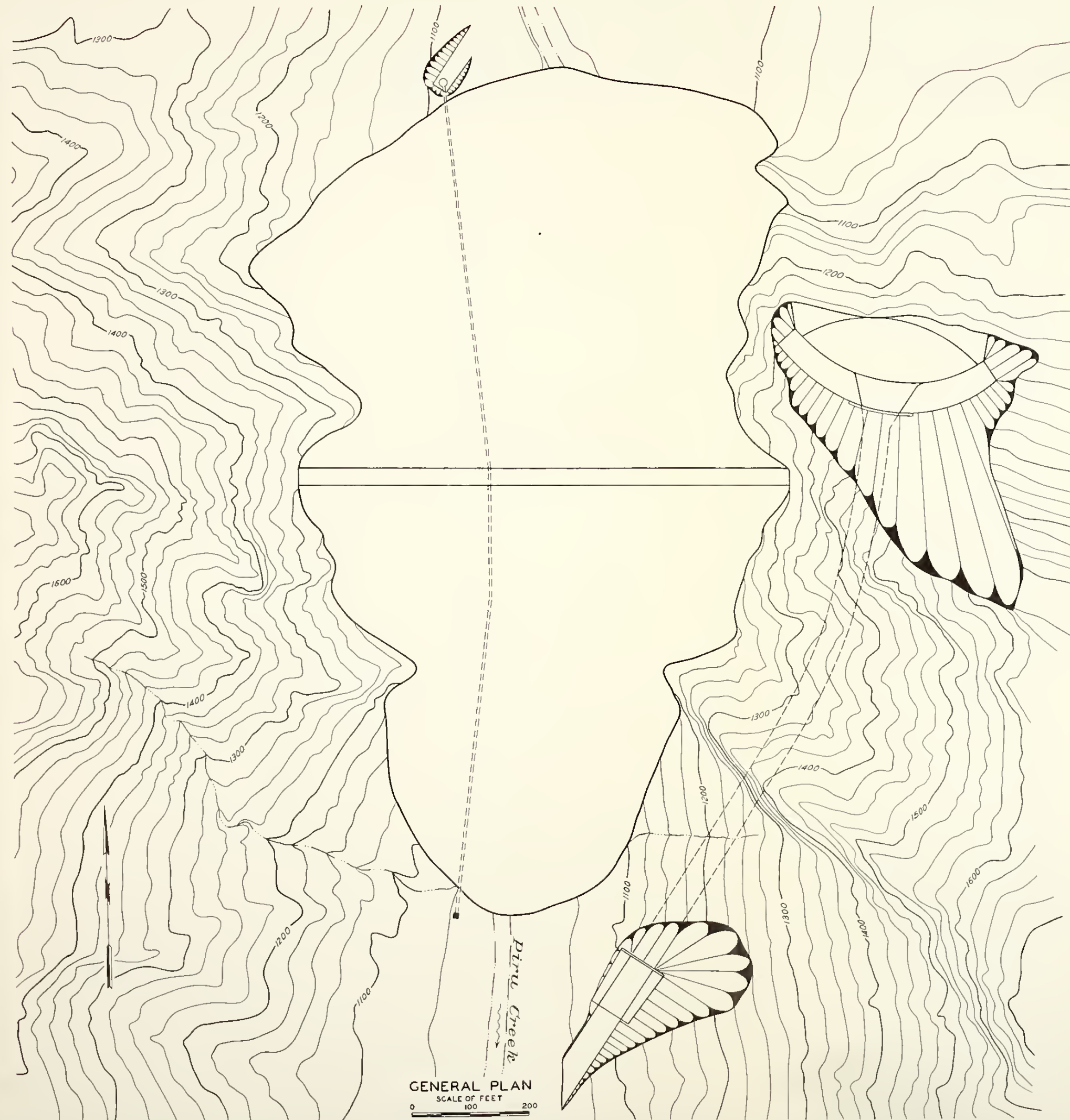






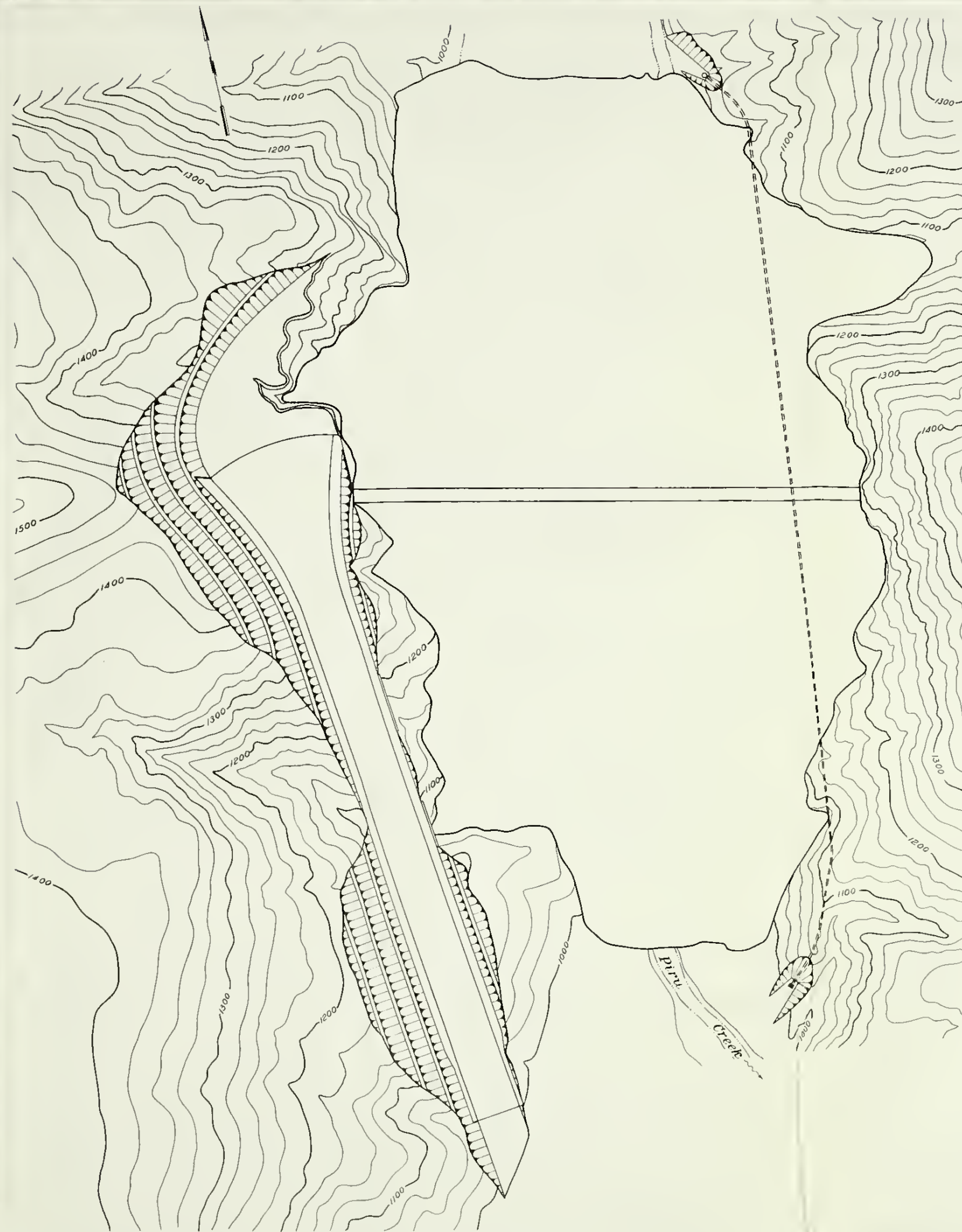
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
UPPER BLUE POINT DAM  
ON  
PIRU CREEK  
RESERVOIR STORAGE CAPACITY OF 50,000 ACRE-FEET



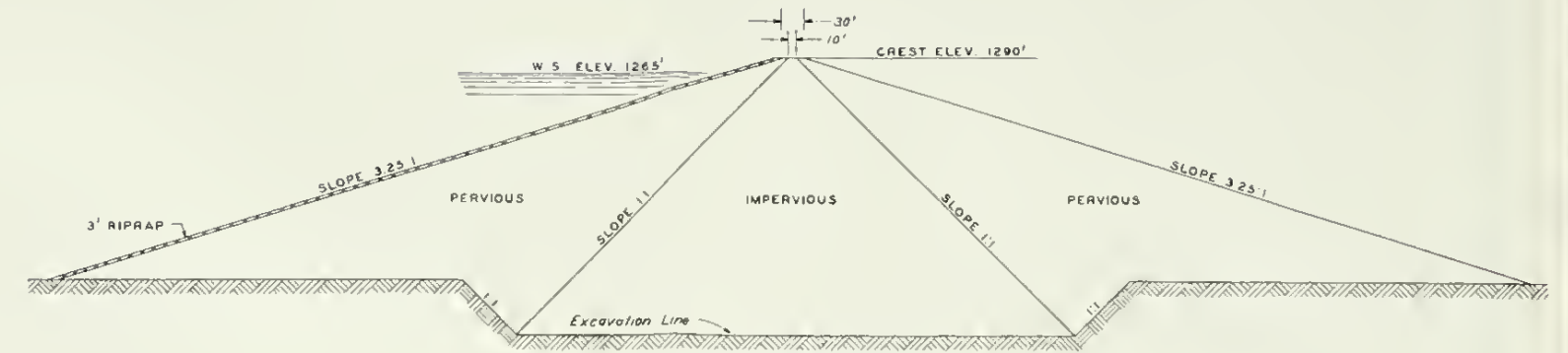


BLUE POINT DAM  
ON  
PIRU CREEK  
RESERVOIR STORAGE CAPACITY OF 50,000 ACRE-Feet

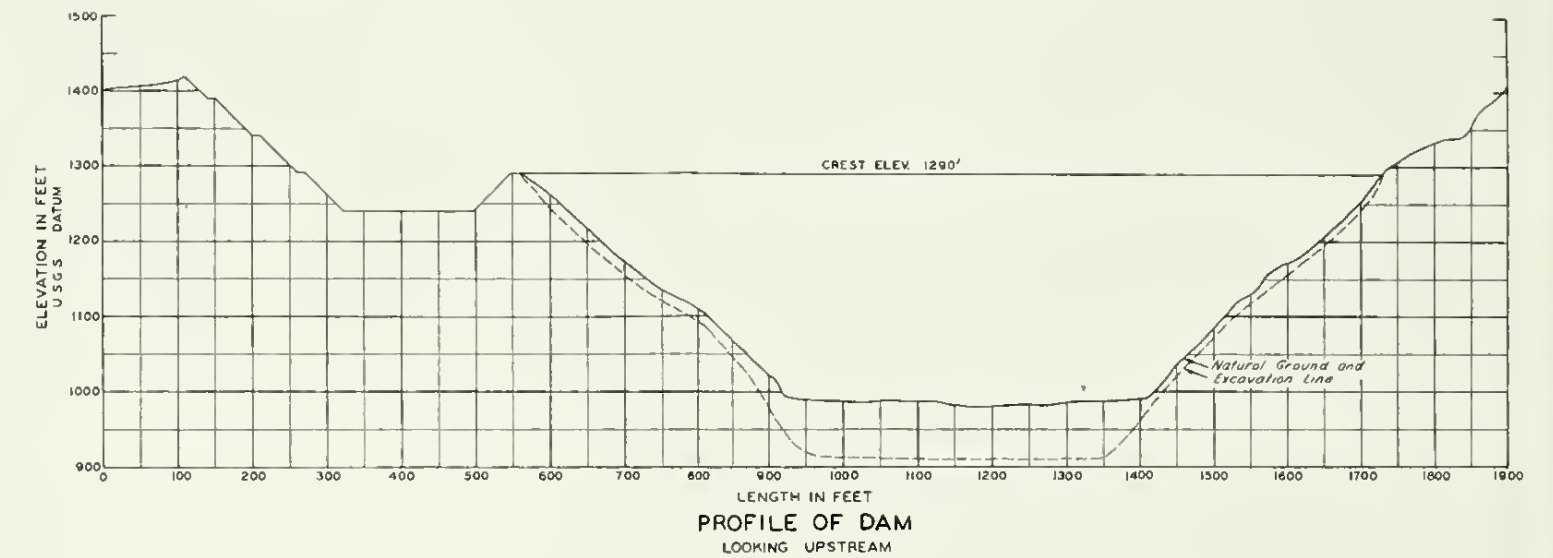




GENERAL PLAN  
SCALE OF FEET  
0 100 200

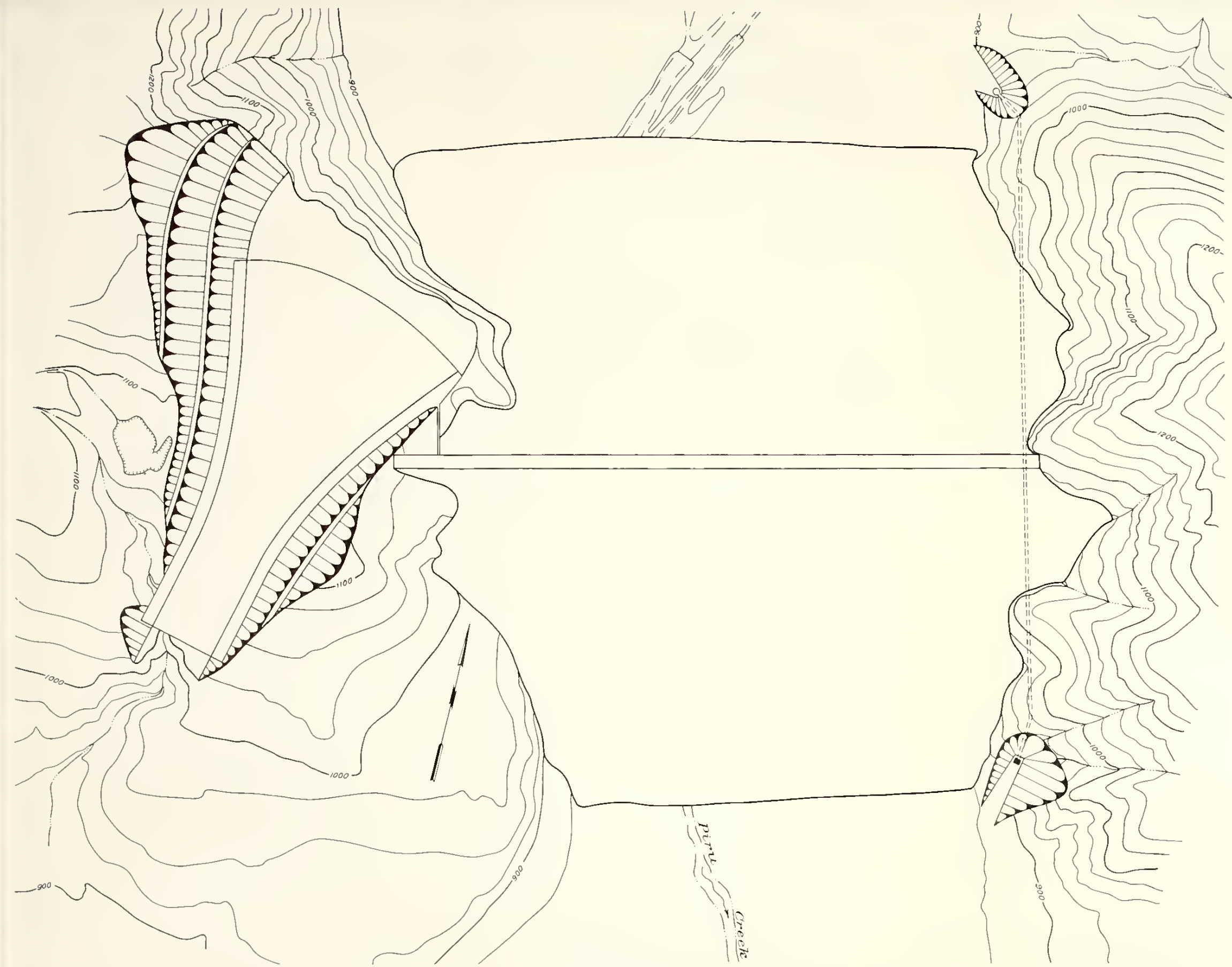


SECTION OF DAM  
SCALE OF FEET  
0 100 200

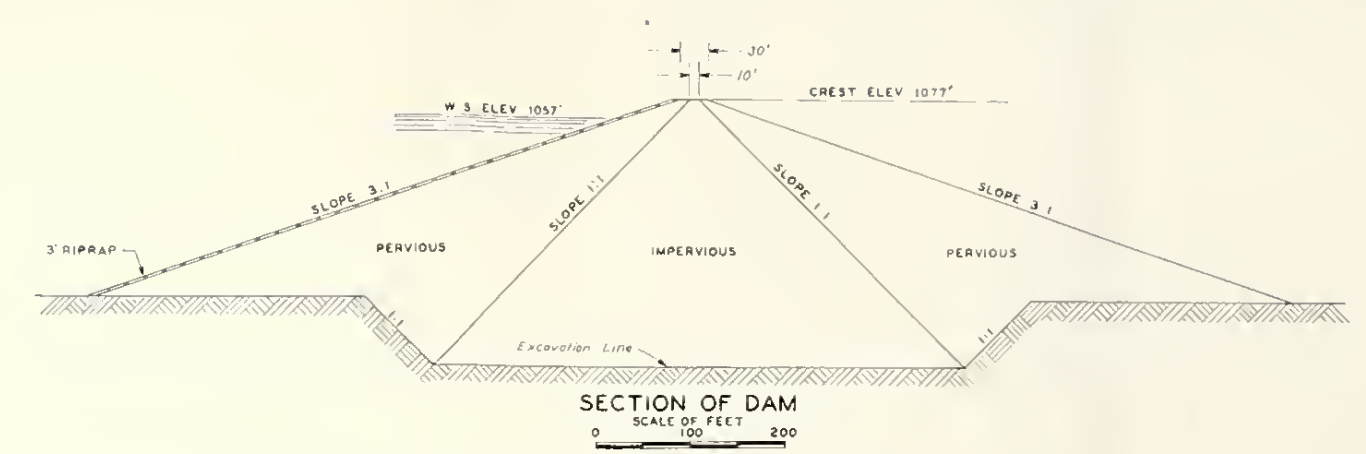


PROFILE OF DAM  
LOOKING UPSTREAM

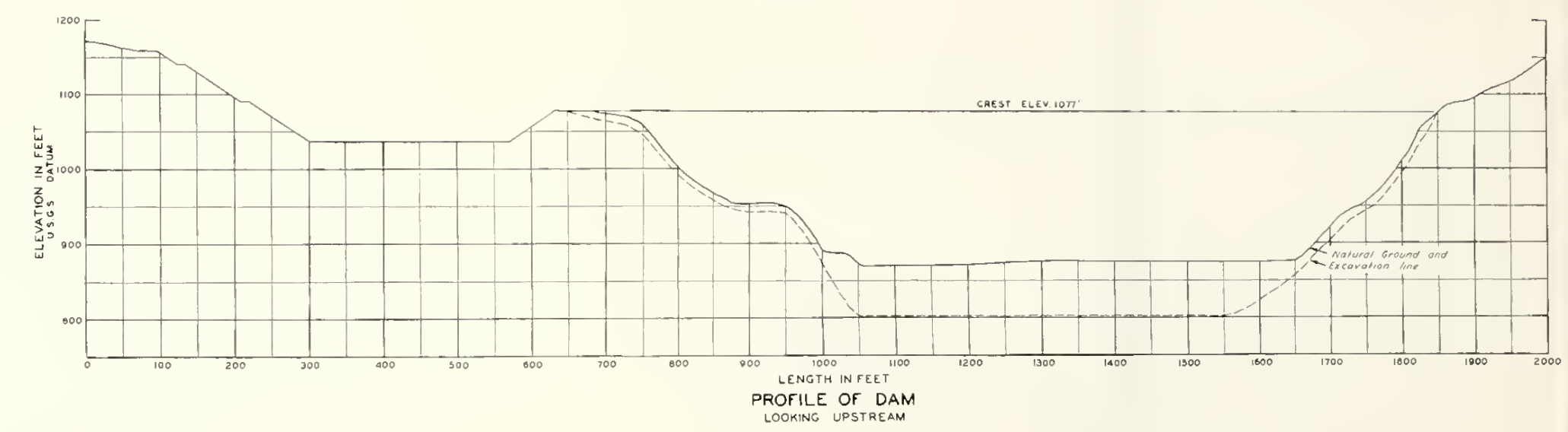
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
DEVIL CANYON DAM  
ON  
PIRU CREEK  
RESERVOIR STORAGE CAPACITY OF 150,000 ACRE-FEET



GENERAL PLAN  
SCALE OF FEET  
0 100 200



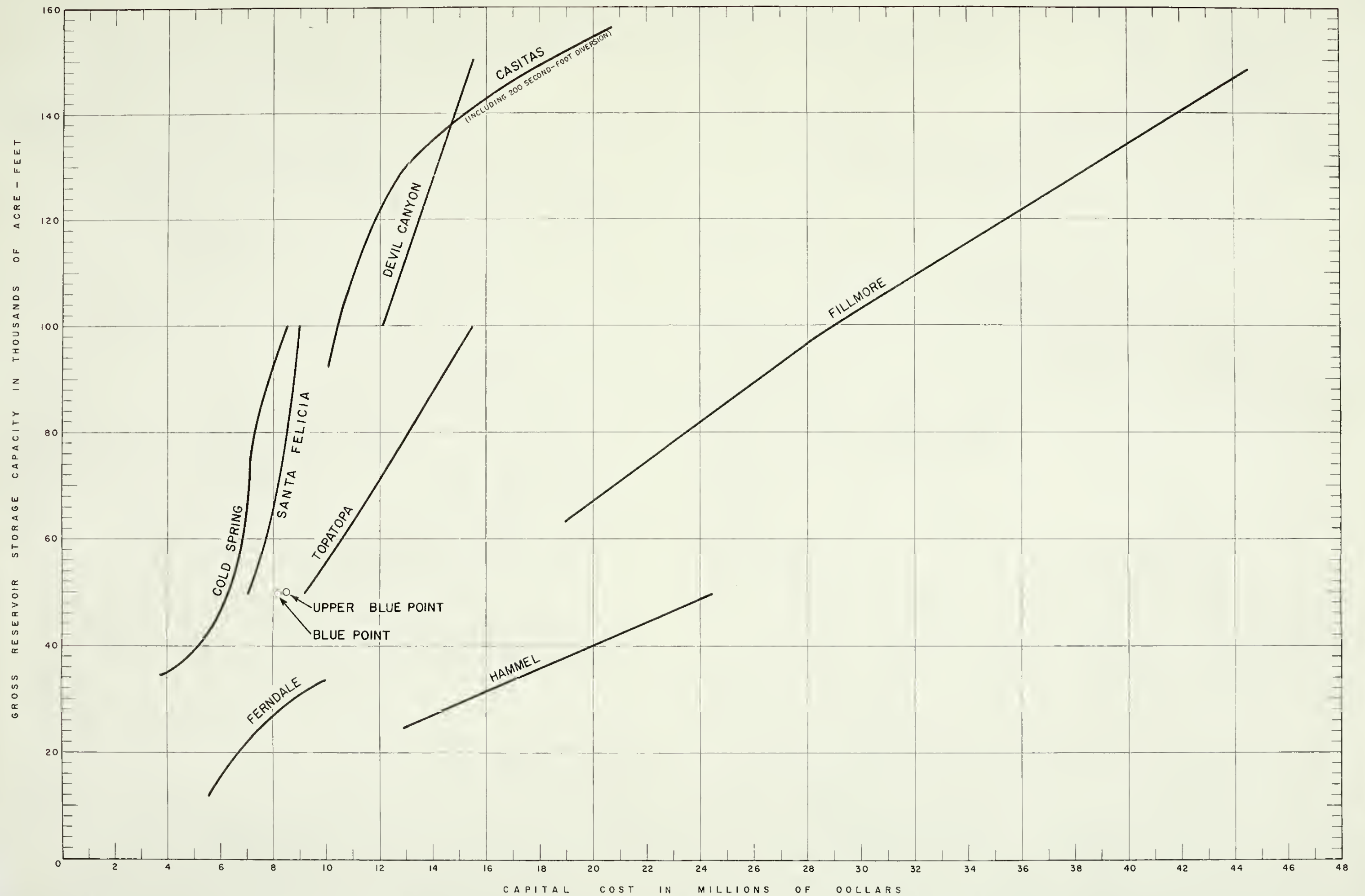
SECTION OF DAM  
SCALE OF FEET  
0 100 200



PROFILE OF DAM  
LOOKING UPSTREAM

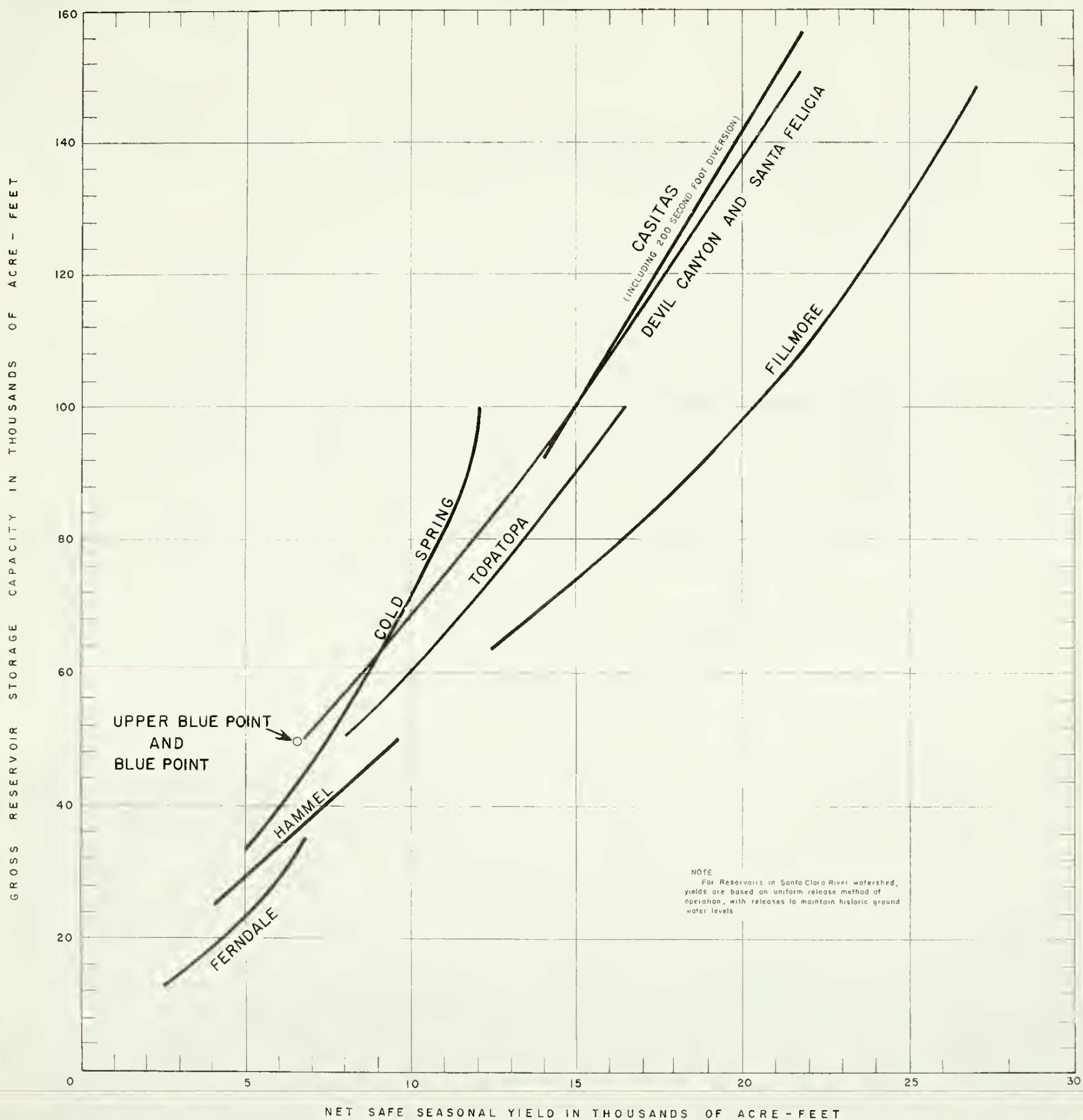
STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION  
**SANTA FELICIA DAM**  
ON  
**PIRU CREEK**  
RESERVOIR STORAGE CAPACITY OF 100,000 ACRE-FEET



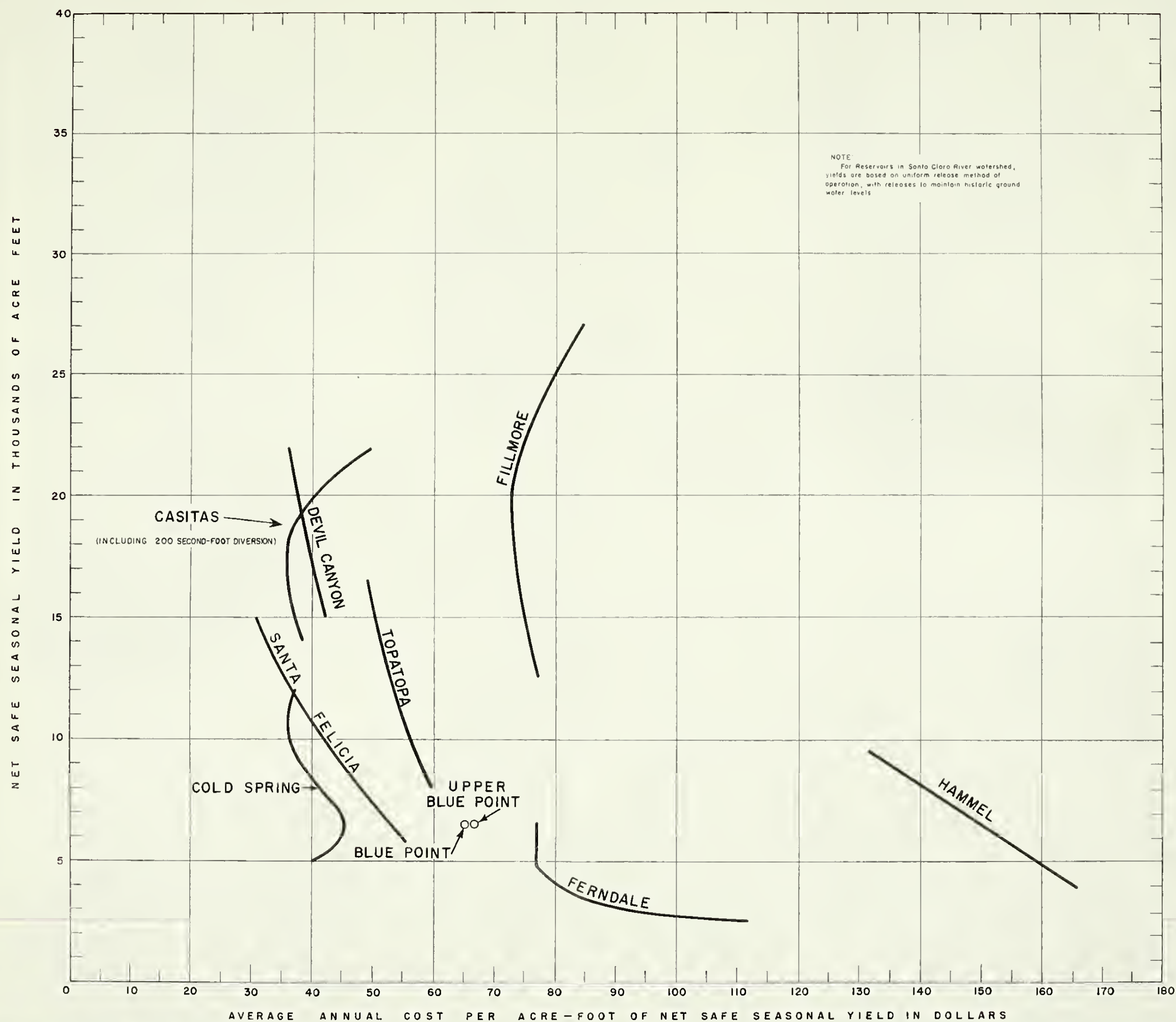


RELATIONSHIP BETWEEN STORAGE CAPACITY OF RESERVOIRS AND CAPITAL COST

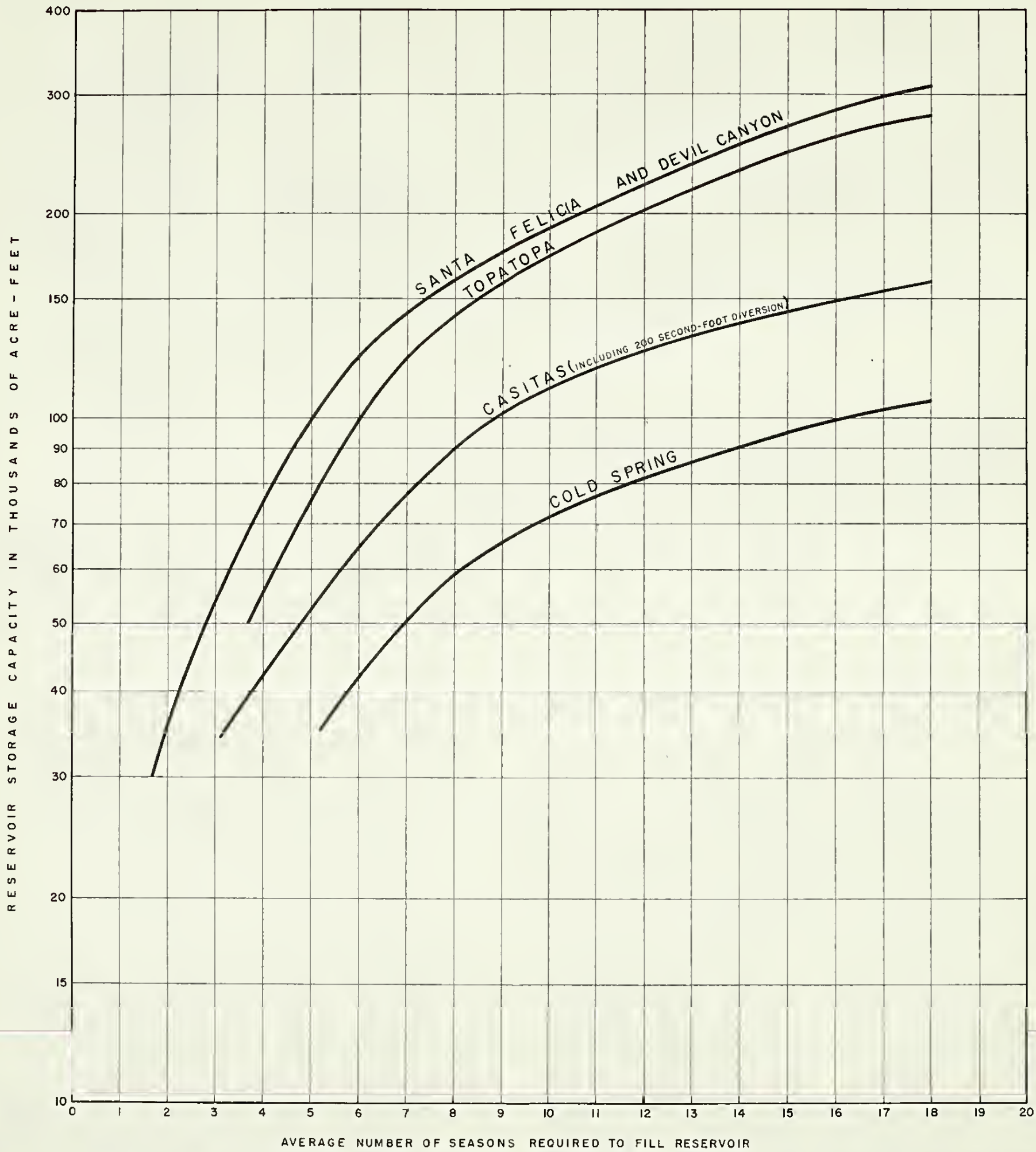




RELATIONSHIP BETWEEN STORAGE CAPACITY OF  
RESERVOIRS AND NET SAFE SEASONAL YIELD

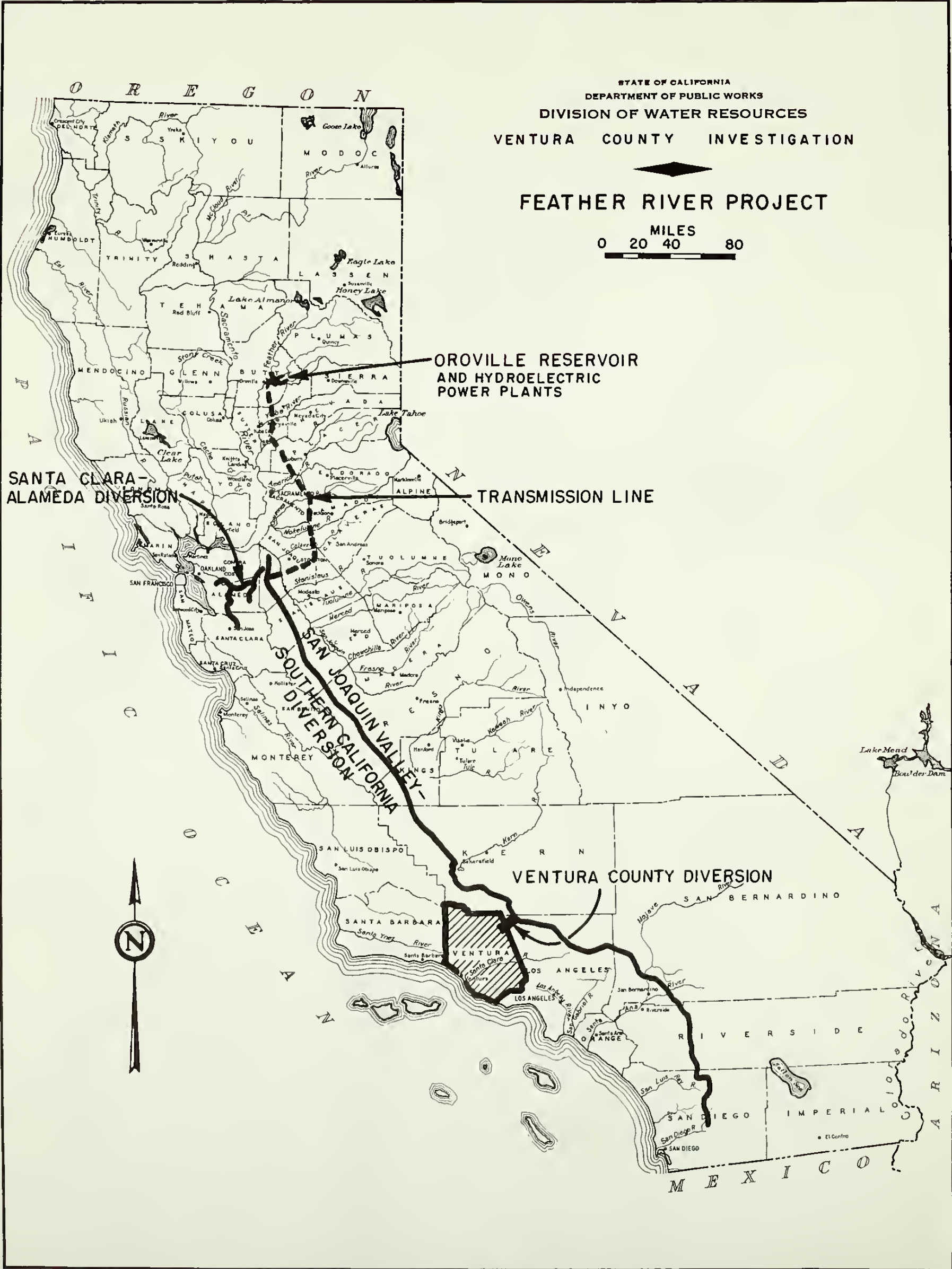


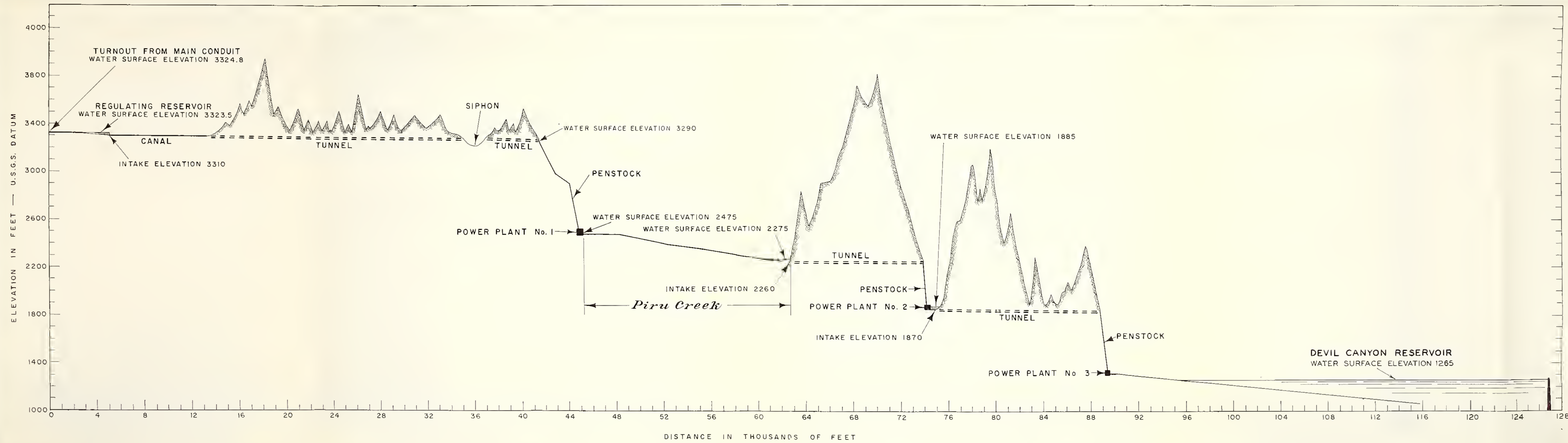
RELATIONSHIP BETWEEN NET SAFE SEASONAL YIELD OF RESERVOIRS  
AND ANNUAL UNIT COST



PROBABLE TIME REQUIRED TO FILL RESERVOIRS  
AFTER CONSTRUCTION



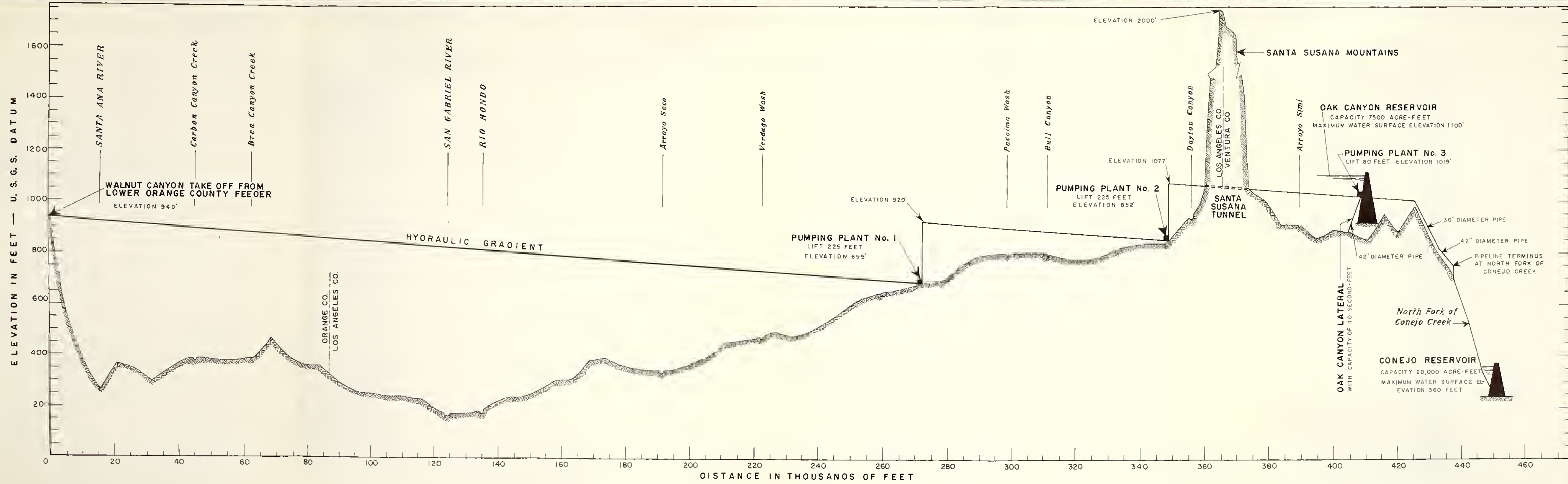




STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

PROFILE OF POSSIBLE VENTURA  
COUNTY DIVERSION  
FEATHER RIVER PROJECT





STATE OF CALIFORNIA  
DEPARTMENT OF PUBLIC WORKS  
DIVISION OF WATER RESOURCES  
VENTURA COUNTY INVESTIGATION

**PROFILE OF PROPOSED VENTURA COUNTY  
AQUEDUCT TO CONNECT WITH SYSTEM OF  
METROPOLITAN WATER DISTRICT  
OF SOUTHERN CALIFORNIA**

**CAPACITY 150 SECOND- FEET**















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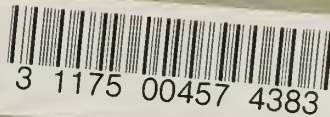
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